Anthony S. Travis

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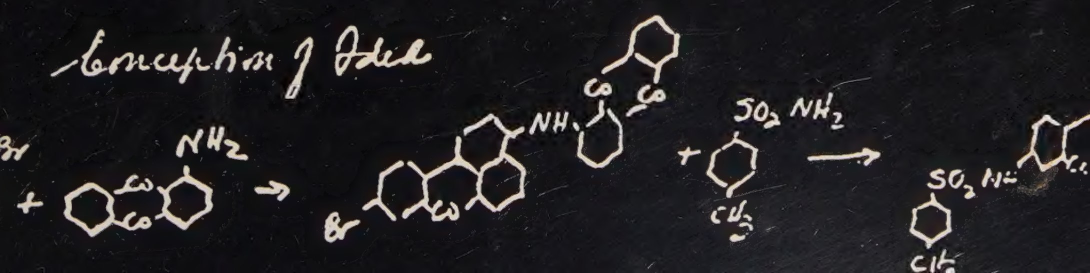

To Gerard H Fortenza
with many thanks
for your help.
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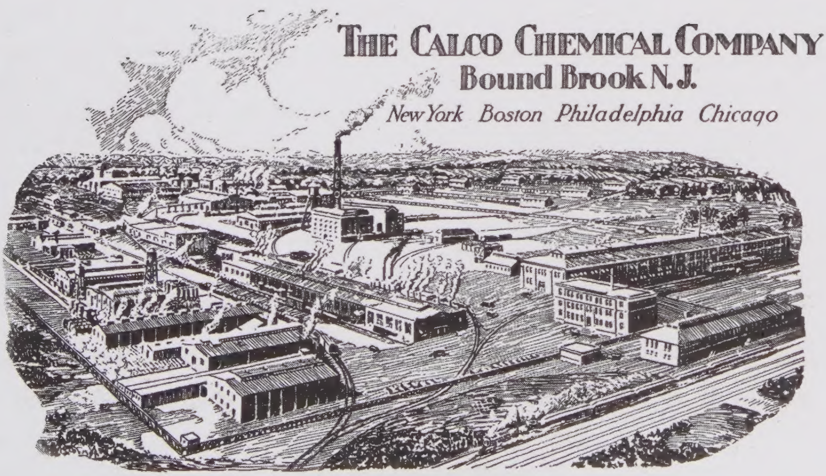

DYES MADE IN AMERICA
1915–1980
The Calco Chemical Company, American Cyanamid, and the Raritan River

Anthony S. Travis

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To the memory of my mother and father

Preface

The Calco Chemical Company was founded in 1915 to manufacture those essential organic chemicals—the intermediates from which synthetic, or coal-tar, dyestuffs were produced—no longer available from war-torn Europe. Its location was near Bound Brook, New Jersey, almost adjacent to the Raritan River. Like many similar start-ups, for several years it had a precarious existence, struggling to expand and establish new markets, in both intermediates and dyestuffs. Calco's future was assured in 1929, just before the Great Depression set in, when it was acquired by the American Cyanamid Company. The same types of chemicals continued to be made at Bound Brook until 1980, as were a host of other artificial products—resins, pharmaceuticals, fibers, and rubber chemicals—that transformed modern life.

Today the Calco factory is as much a part of history as other events, more enduring in collective memory and in books, that took place at and close to the site. Most famous was the Battle of Bound Brook on Palm Sunday, 1777, when British soldiers descended on a small group of Americans, who sustained many casualties and were forced to retreat. Later in the year, George Washington camped nearby at Middlebrook Heights, and raised there, for the first time, the Betsy Ross flag, better known as the stars and stripes. Washington returned in the winter of 1778–79. He noted that the ground at Bound Brook close to the Raritan River was marshy and thus unsuitable for battle. In 1779, Loyalist Queen's Rangers attacked the home of the van Horne family that today occupies the last piece of undeveloped land on which the Battle of Bound Brook was fought.

The site also contributed to the stories of other battles. In the 1940s, the Calco factory supplied Allied and American armed forces with vital chemicals for explosives, dyes for uniforms and locating airmen downed at sea, camouflage colors, wonder drugs to heal the wounded, plastics for laminating maps, adhesives for the construction of aircraft and boats, and products for strengthening the tires on which armored divisions relied. When in 1943 the factory received its prestigious Army–Navy E pennant, no less a personality than the great American singer and actor Paul Robeson was present to applaud the workers with a recital. At that time, the Van Horne House served as Calco sales offices.

The Raritan River played a deciding role in the selection of the site for the Calco factory, for the van Hornes to build their home, and for Revolutionary soldiers to encamp nearby. Seventy-five miles in length, the Raritan is the longest river completely in the State of New Jersey, and meets open water at Raritan Bay. Its seasonal flow varies widely, and at times in the summer can be much reduced by drought. After the winter, as snow melts on higher land, the Raritan and its branches can turn into raging torrents that in a moment submerge whole areas, as they—and hurricanes—did to Calco on occasions. In normal times, a considerable amount of the Raritan's volume was diverted to Calco, whose effluent was discharged downstream, causing sucker and other fish to seek out more hospitable habitats. By 1930, Calco was seen by many to be the major contributor to the degradation of the Raritan's appearance and the loss of its aquatic life.

What follows is the story of the Calco factory and its relationship with the Raritan River, of how groups of people cared about creating useful products and others cared about reversing the impact of industry on the river. That the factory no longer exists is not altogether the outcome of environmental concerns, but about the way in which technology and its management changes. It is a 20th-century story that resonates into the 21st with the transformation of chemical industry and remediation of the now-flattened Calco site. By making extensive use of the writings and voices of those who were engaged in the affairs of the factory, from within and without, one area of technological achievement is measured against the way it was managed, and the way in which it burdened a nearby amenity.

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Acknowledgments

This book grew out of my studies into the development of the synthetic dyestuffs industry—forerunner of the modern organic chemicals industry—at the Sidney M. Edelstein Center for the History and Philosophy of Science, Technology and Medicine at The Hebrew University of Jerusalem. I have profited immeasurably from assistance provided by former American Cyanamid chemists, most of whom spent all or part of their careers at the corporation's Bound Brook facility in New Jersey. During the years 2001 and 2002, they shared with me their formidable knowledge and insights gained from tremendous breadth of experience.

I owe special thanks to three individuals: Dr. Erwin Klingsberg, at Bound Brook during 1946–81, who provided copies of internal reports and correspondence, some concerning motivation of chemists and corporate policy, miscellaneous American Cyanamid documents, including research newsletters and papers, and, most especially, reminiscences of his time in the employ of the corporation; Dr. Jay Leavitt, who joined Bound Brook in 1944 and spent a varied career with American Cyanamid, and who kindly read an early draft of the first part of this study, drew my attention to a number of errors, and provided considerable additional information—sometimes by drawing on a network of Bound Brook contacts—about people, processes, and products; and Dr. Isaiah Von, at Bound Brook during 1946–81, who supplied some of the most important background material, including descriptions of the Bound Brook site and what went on in various buildings, and answered many technical questions.

Ben H. Loper and Gerard (Jerry) A. Forlenza, presidents, successively, of American Cyanamid's Organic Chemicals Division during the 1970s, provided perspective on that important and difficult period in the affairs of American Cyanamid and the chemical industry in general. Dr. William (Bill) B. Hardy, research administrator, with four decades of experience at Bound Brook, patiently dealt with a number of my questions. Dr. Richard D. Madison, who joined Bound Brook from Cyanamid's Stamford research laboratories in 1958, provided useful information on research activities and policy.

Chemical engineer Dr. C. Marsden Vanderwaart generously allowed me to reproduce extracts from his reminiscences of Bound Brook. Dr. Paul Stonehart, of Stonehart Associates, Inc., and formerly at the Stamford laboratories, provided background on research and other activities in the 1960s.

Also valuable were discussions with: Edelstein International Fellows in the History of Chemistry and the Chemical Sciences, in particular Ute Deichmann (University of Cologne), Peter J. T. Morris (Science Museum, London), Carsten Reinhardt (University of Regensberg), John Kenly Smith Jr. (Lehigh University), and Kathryn Steen (Drexel University, also former Edelstein International Student); philosopher of technology Steven L. Goldman (Lehigh University, and Sidney M. Edelstein Center Senior Fellow); and historian of the environment Jeffrey K. Stine (National Museum of American History, Smithsonian Institution). Dr. Morris applied to great effect his deep knowledge of European and American chemical industry. The contributions of, and interactions with, the following, at workshops organized by the Sidney M. Edelstein Center, were also useful: Joyce Bedi, Arthur P. Molella (historian and director, respectively, Lemelson Center for the Study of Invention and Innovation, National Museum of American History, Smithsonian Institution), and Robert H. Kargon (Johns Hopkins University) ("Places of Innovation: Sites of Discovery," November 2001); Christian Simon (University of Basel), Martin Forter (University of Basel), Joel Tarr (Carnegie Mellon University), and John Kenly Smith Jr. ("The Environment: Historical Context and Present-day Perspectives," November 1999); and participants at the "History of Chemistry Workshop" (July 1998), on which occasion I presented the first results of my research into the Calco Chemical Company. The latter event was held in collaboration with the Commission on the History of Modern Chemistry of the International Union of the History and Philosophy of Science, Division of History of Science, an organization related to UNESCO through the International Council of Scientific Unions. Christian Simon, as Gordon Cain Fellow 2000–2001 at Chemical Heritage Foundation, organized a workshop on chemical industry and the environment in February 2001 that provided a unique opportunity to compare and contrast European and American approaches to the handling of waste. Civil

works historian Martin Reuss (Office of History Headquarters, U.S. Army Corps of Engineers) kindly made available Carroll Pursell's draft chapters from a forthcoming study of regulatory developments in the U.S. Army Corps of Engineers.

I thank Hava Nowerstern, curator, the Sidney M. Edelstein Library, and staff for promptly dealing with my many queries concerning the Edelstein collections in the history of dyes and dyeing, and history of chemistry. I am indebted to Hannah Kerwin, director, Bound Brook Memorial Library, New Jersey, and staff for assistance with access to the *Bound Brook Chronicle*, various documents, and the files of Dr. Neil M. Mackenzie, and permission to review, cite, and quote from this material. I also thank the staff of the following libraries: the Avraham Harman Science Library, The Hebrew University of Jerusalem; the Jewish National and University Library, Jerusalem; Dartmouth College Library, Dartmouth College, Hanover, New Hampshire; the Donald F. and Mildred Topp Othmer Library of Chemical History at Chemical Heritage Foundation, Philadelphia; the Science Reference Library, London; The British Library, London; Imperial College and Science Museum Library, London; and the library of the Chartered Institute of Water and Environmental Management, London.

Dartmouth College has graciously provided permission to publish extensive extracts from the papers of Victor L. King held at Dartmouth College Library.

Acknowledgments are also due to: Professor T. Alan Hatton, director, David H. Koch School of Chemical Engineering Practice, Massachusetts Institute of Technology (MIT); John I. Mattill, former director of publications at MIT and editor of its *Technology Review*; Susan Becker, BASF Archives, Ludwigshafen, Germany; Ellen Callahan, New Jersey State Archives, Department of State, Trenton; Terri Santella, law librarian, Federal Court of Appeals, Washington, D.C.; and staff at the Fairchild Aerial Photography Collection, Whittier College, California.

For permission to adapt published figures I thank the following: The American Chemical Society ("Urethane Plastics: Polymers of Tomorrow," *Industrial and Engineering Chemistry* 48 [September 1956], 1383–91, on 1388); *Chemistry and Industry* (H. G. Rains, "The Paint Industry as a User of Heavy Chemicals," June 20, 1964, 1047–

58, on 1051); and the Water Environment Federation (Sheppard T. Powell and James Lamb III, "Industrial and Municipal Cooperation for Joint Treatment of Wastes. I. Industry Approach and Position," *Sewage and Industrial Wastes* 31 (1959), 1044–52, on 1046). For permission to reproduce figures and photographs I thank the editor and publisher of *The Indicator*, journal of the North Jersey Section, American Chemical Society, and The McGraw-Hill Companies (*Hackh's Chemical Dictionary*, 3rd edition [London: J. & A. Churchill, 1944], 573, 728, 818).

I thank Joan E. Mentzer for editorial assistance, my brother Kenneth H. Travis for library research, and David Darom and staff at The Hebrew University of Jerusalem for preparing figures.

Finally, I owe a debt of gratitude to the late Dr. Sidney M. Edelstein and the Sidney and Mildred Edelstein Foundation, whose support of the Edelstein Center and Edelstein Library at the Hebrew University made this research possible. I trust that through this study I have continued in the tradition of Dr. Edelstein's own research into the history of dyestuffs and textile chemicals, chemistry, technology, and Americana, as reflected in the rich resources of the Edelstein Library. Thanks also to Ruth Edelstein Barish and her family for donating the annual Edelstein Award for Outstanding Achievements in the History of Chemistry, and also the Edelstein Prize (formerly the Dexter Prize) of the Society for the History of Technology, both originally founded by Sidney Edelstein to encourage and recognize excellence in historical scholarship.

Introduction

This study takes its title from *Dyes Made in America, 1915–1940* (Calco Chemical Division, American Cyanamid Company), a celebration of a quarter-century of successful imitative and innovative manufacture of synthetic dyestuffs close to the town of Bound Brook in northern New Jersey. The text of that lavish company-sponsored publication—bound in blue cloth with the title stamped in metallic silver leaf—was prepared by the noted pioneer of the history of the American chemical industry, Williams Haynes.[1] For his studies Haynes was to become the second recipient of the prestigious Dexter Award (now Edelstein Award) of the Division of the History of Chemistry of the American Chemical Society, in 1957, the year in which he completed work on what was to have been a book to mark the fiftieth anniversary of the founding of American Cyanamid.

At the outset, it should be stated that this is not a company-sponsored or commissioned book, nor an official history in any way. It is the story of a major division of one of the great American chemical corporations of the 20th century that no longer exists, and a reminder that, as the in-house journal *Bound Brook Diamond* pointed out in 1953, the "Garden State" once possessed "the greatest concentration of the chemical industry in the U.S. and perhaps in the world." Along the way, this study explores what I believe to be the most important areas of current interest to historians of chemical and other technologies: processes of invention, technology transfer, diversification (in this case from dyestuffs to pharmaceuticals and new polymers), corporate growth based on research and development, management of innovation, and environmental issues. The latter is the main point of departure from previous histories of chemical firms. Each aspect receives coverage proportional to its perceived significance at the present time.

The Calco Chemical Division of American Cyanamid, formed in 1939, was named after the earlier Calco Chemical Company that began the manufacture of dye intermediates at Bound Brook in 1915, and in 1929 was acquired by American Cyanamid. During the following decade the United States took second place, after Germany, in the league of international dye makers. Calco, along with DuPont, the National Aniline & Chemical Co., division of Allied Chemical & Dye Corporation (formed in 1920), and the General Aniline Works (from 1939 known as General Aniline and Film, or GAF), produced 60 percent of dyes made in America, which by 1950 had "now become the world's largest producer and exporter of coal-tar dyes."[2] Dyes continued to be made at Bound Brook until 1980, after which time American Cyanamid's operations were concentrated on the life sciences, though not at Bound Brook. Similar stories of the transition from dyes to pharmaceuticals and life sciences were repeated elsewhere in North America and had strong parallels in Europe, where synthetic dye manufacture had commenced in the 1860s. Moreover, in the year 2000 the last vestiges of the original American Cyanamid, once the fourth largest American chemical corporation, became the property of BASF of Ludwigshafen, Germany, once the leading international dye maker and pioneer of science-based chemical industry. By then, the Bound Brook factory had become just another of the many vanishing industrial sites where once the foundations of the modern American organic chemicals industry were laid down.

The yardstick against which progress at companies engaged in dye and allied chemical manufacture may be measured is undoubtedly BASF. Like American Cyanamid, BASF had a long association with dyes and agricultural products. Both firms' early-20th-century fertilizers were reliant on the capture of atmospheric nitrogen, though by different chemical reactions: novel electrochemical and high-pressure processes, respectively. More relevant here is the fact that Calco's first intermediates and dyes were based on BASF and other German technology, much of it adopted by American manufacturers after the outbreak of World War I, and especially after the United States became a belligerent in 1917.

Dyes, melamine resins, and sulfa drugs had once made American Cyanamid and its Calco Chemical Division one of the wonders of research-led corporate America. Calco was, in the words of former Bound Brook chemist Isaiah Von, "the only start-up [from the World War I period] in the chemical business that grew of its own initiative ... the rise and fall of the plant makes a fascinating story. The founders were very enterprising and outstanding people who were able to continue the plant's growth throughout the Great Depression in the 1930s. I think the plant reached its zenith about 1946." Von also observes: "Its decline began seriously during the 1960s and roller coasted to the end in 1981–82. There are a number of reasons for this, foremost of which is, of course, poor management. It is a similar story to what happened to many of our industrial institutions in the U.S."

There are three main reasons why I have chosen to focus on this particular manufacturing site. First, it is one of the few locations where large-scale dye manufacture was commenced at a critical period in 20th-century American history and that were subsequently at the forefront of the expansion, through diversification, of that nation's chemical industry. Second, through these activities, Bound Brook provides what is probably the best example of an American operation that can be directly compared with a European firm, in this case BASF. Third, there is a wealth of resource material that is rarely available to the historian of chemical technology. Included are transcripts from lectures, reminiscences, and correspondence, and quotes from editorials and interviews, that, for all their biases and other failings as historical documents and sources, capture the spirit of what it was like to be part of the American chemical industry at various times in the 20th century. They provide a window on the past that minimizes the need for reconstruction or conjecture, and compensates for what is lost. This is the main purpose of the gathering of evidence. No apology is made for the fact that in this chronicle there is probably far more than most readers will need to know, since, even if not lost in the future, some of the material may not surface again without diligent and time-consuming investigations, involving visits to several locations.

Though fully representative of responses to needs of the time, American Cyanamid's Bound Brook dye-making division, either alone or working with the corporation's satellites, was in many respects atypical. Structurally and organizationally, it had progressed over two decades from a mainly intermediates manufacturing outfit to an integrated chemical city involving every stage from research to a range of services that assisted users of its products. It was exceptionally innovative, even if, as research and development (R&D) manager Jay Leavitt points out, in "a copying sort of way." In 1927, a formal Research Department emerged out of the various R&D activities at Bound Brook, and from 1937 much of the corporation's research, though by no means all, was undertaken at new "General Research Laboratories" located in Stamford, Connecticut. Bound Brook became a world leader in physical instrumentation—particularly spectrophotometry—as applied to dyestuffs and the intermediates from which they were derived. Bound Brook pioneered instrumental color standardization and color matching for dyestuffs, and, such was the status of the facility in the international dye industry, for several years its scientists dominated the American editorial board of the dye-makers' and dyers' bible, the *Colour Index*.

As with chemical firms in Europe, American Cyanamid's Calco Chemical Division diversified successfully into pharmaceuticals using dye intermediates, and was responsible for the development of certain modern and ubiquitous resins and plastics, particularly those based on melamine. The tremendous expansion of the automobile industry created demands for Calco's plastics and aromatic intermediates, the latter in the form of products for the tire industry, mainly at Goodyear. These were followed after World War II with acrylics, polyurethanes, and new health and agricultural products, including Avenge herbicide (discovered through research at Bound Brook).

While the foregoing summary suggests why this study concentrates on only one of American Cyanamid's facilities, the choice is to some extent also fortuitous. This arises from the fact that resources available to me at the Sidney M. Edelstein Center for the History and Philosophy of Science, Technology and Medicine at The Hebrew University of Jerusalem, and the associated Sidney M. Edelstein Library, in particular its Edelstein Collection that focuses mainly on dyestuffs, are confined almost exclusively to activities at Bound Brook. Moreover, an account of one of the most important American dye-making factories provides a plausible excuse to complete a trilogy that delineates the rise, development, and, indeed, the decline, of sectors of dye making in both Europe and North America. First, in *The Rainbow Makers: The Origins of the Synthetic Dyestuffs Industry in Western Europe* (1993), I concentrated on the emergence of the industry in England, France, Germany, and Switzerland, and the dominance of Germany by 1900. Then, jointly with Carsten Reinhardt, I turned to the one individual responsible for the rise of much of the German dye industry, the inventor Heinrich Caro at BASF

(*Heinrich Caro and the Creation of Modern Chemical Industry* [2000]). The power of the German dye industry, particularly its control of patents through the efforts of Caro and others and its strong marketing organizations, suppressed the development of the industry in the United States, but only until 1914. Then, with supplies cut off by Germany, which required dyes and their intermediates for military purposes, and also by the British blockade on German shipping, the American chemical industry and textile manufacturers pursued an energetic strategy aimed at self-sufficiency in dye manufacture. For this they embarked on the production of intermediates, some of which were also necessary for the manufacture of modern explosives.

The Calco Chemical Company, one of the longer-lasting outcomes of the American response, and the last part of the trilogy, thus usefully completes the move from macro situation to biography and then to a micro case study. There is a strong connection among all three stories, but especially between the second and third, since many of the Bound Brook products and intermediates were the original inventions of Caro or of his colleagues at BASF. This makes BASF the ideal example for providing the prehistory of the dye industry. Moreover, in the 20th century Calco can be compared with BASF (from 1925 part of I.G. Farben) as they responded to different political and economic conditions, and to new opportunities. Such comparisons were even part of corporate strategy, particularly American Cyanamid surveys in Germany immediately after World War II in connection with the United States FIAT (Field Intelligence Agency, Technical) investigations into German science and technology.

A few words on the other leaders of the U.S. dye industry during its heyday are not amiss. Firstly, E. I. du Pont de Nemours & Co., Inc., of Wilmington, Delaware, better known as DuPont (previously the company name had a space between the two words, but the current spelling will be used in this work). The rise and decline of its Dyestuffs Department (Organic Chemicals Department, or Orchem, from 1931) has been well covered by historians of chemical industry, business, and technology. The most impressive study was part of a large project undertaken by David Hounshell and John Kenly Smith Jr., who in great detail have shown how DuPont's purchase of dye technologies, and research into new dyes, was highly successful, though its marketing strategy was less so. In the 1930s, DuPont was the leading American chemical corporation, encompassing several sectors of chemical manufacture that arose from its entry into dye research. Then there was the group of firms, Schoellkopf, National Aniline, Barrett, and Benzol Products, that in May 1917 associated to form what was soon known as National Aniline & Chemical Co., Inc. (NACCO; later part of Allied Chemical & Dye Corporation). The I.G. Farben-owned GAF had originally started out at Linden, New Jersey, in 1919 as a branch of the Grasselli Chemical Company, that in 1924 formed, jointly with Bayer, the Grasselli Dyestuff Corporation (later the General Aniline Works). With the associated Rensselaer facility, New York, Grasselli Dyestuff once supplied several American-made dyes. The Linden facility, also known as Grasselli, concentrated on the manufacture of intermediates.

Calco provides an interesting contrast with European firms in part because of the level of technology transfer and how it was achieved. While during World War I, DuPont shared information with Levinstein Ltd in Manchester, England, Calco resorted to German textbooks, an American academic consultant, and a few industrial chemists and engineers. Through trial and error—a great deal of both—and a government contract, expertise in intermediates manufacture was built up. After the war, Calco and other American start-ups were able to share the spoils of German inventions when sequestered German patents were made available through an organization called the Chemical Foundation. Capabilities were built up in the transformation of patent recipes and new knowledge into sophisticated and useful products. During the 1920s, there were opportunities to gather ideas from Europe, notably amino resin processes, and to absorb American firms with the requisite proprietary know-how. The latter became important when Calco's attempt to dominate the manufacture of certain dye intermediates in America failed. A satisfactory response was found in the purchase of firms that made different types of dyes, mainly from the same intermediates that Calco manufactured, and often for different markets.

Early in 1929, Calco's expansion, hampered by lack of funds and difficult trading conditions, was made possible through its acquisition by American Cyanamid, a corporation increasingly anxious to diversify away from fertilizer manufacture as the impact of recession in agriculture and worldwide overproduction in nitrogen products drove home. Calco became the dye-making hub for American Cyanamid, which purchased other, though smaller, dye and pigment makers that were brought under the control of the Calco subsidiary. Then in 1930, American Cyanamid purchased the Lederle Antitoxin Company, a specialist in the production of biologicals. Subsequently, Lederle and Bound Brook collaborated in many areas, especially the development of sulfonamide drugs that relied on the technology of dye intermediates; Bound Brook became an important supplier of intermediates and products for both Lederle and Cyanamid's agricultural divisions. These were the progenitors of the transformation of American Cyanamid into a life sciences, pharmaceuticals, and agricultural products corporation half a century later.

Bound Brook scientists also undertook important studies into hygiene problems associated with the manufacture of aromatic chemicals. This included the occurrence of cyanosis or "blue lip" among workers engaged in the handling of certain intermediates, particularly nitrobenzene and aniline. At the end of the 1930s, through the use of new instrumental methods, Bound Brook medical officers produced the definitive study on the mechanism for this phenomenon. During the 1940s, extensive toxicological work on Calco's new products was undertaken by Robert A. Kehoe and coworkers at the Kettering Laboratory of Applied Physiology, University of Cincinnati.

In 1939, the newly formed Calco Chemical Division also diversified successfully using calcium cyanamide as the basis for melamine resins and plastics. After 1945, American Cyanamid, in common with other American firms, continued to exploit German dye-making and chemical technology through the availability of reports of Allied investigators. This included vat dyes, particularly the processes for soluble members of the class. Polyurethane technology, discovered at the Leverkusen factory of I.G. Farben in the late 1930s, and dependent on the availability of derivatives of coal-tar amino compounds, was a natural choice for American Cyanamid. The technology transfer was efficient since, insofar as historians Peter J. T. Morris and Raymond G. Stokes have shown, what was important were the original discoveries and ideas, which in American hands were transformed into profitable products.[3]

In 1934 the corporate headquarters of American Cyanamid were moved to the top floors of the new RCA Building in New York City's Rockefeller Center. This was a reflection of the then-high status and great investment opportunities represented by large and innovative chemical firms, and their confidence in purpose and proven successes. Access to fresh capital for expansion was close at hand in Wall Street and Manhattan. After 1945, the so-called "wonder drugs" and novel plastics, including products developed during World War II that were now adapted for the civilian economy, maintained the aura that kept the chemical industry in the spotlight for another decade. In 1954, in a major reorganization, the Calco Chemical Division became the largest component of American Cyanamid's new Organic Chemicals Division. From this time the management structure was based on a chain of command controlled, successively, by a Board of Directors, a General Staff (later called Executive Committee), general managers of divisions, plant managers, and departmental managers, who in turn oversaw managers of subdepartments, mainly research and development, manufacturing, and marketing.

It was from around 1960 that the chemical industry, while profitable and still an attractive investment, was no longer able to promote itself as the leading cutting-edge science-based enterprise capable of sustained inventive and innovative activity. American Cyanamid relied on steady income from its dyes, polymers, resins, and pharmaceuticals. In 1962, the American Cyanamid corporate headquarters were moved from New York to Wayne, New Jersey.

Through Lederle, and its own base in agrochemicals, American Cyanamid moved smoothly into the life sciences from the 1970s, a transition that accelerated the collective retreat and decline of traditional, mature lines, particularly dyestuffs. Again, the same path was followed elsewhere, especially among the founders of the European dye industry, such as Bayer, Hoechst, CIBA, and Geigy, many of which had acquired or began to acquire American factories. BASF, which lacked a tradition of pharmaceutical research, saw opportunities in North America for synthetic fibers, a market in which it expanded greatly from the late 1970s. In general, however, European firms tended to retain their dye businesses longer than their American counterparts.

For historians of chemical technology and business, the complex diversification of American Cyanamid, which was almost certainly without equal in the United States before 1939, presents a daunting challenge. Here it is tackled through the networks of products and people, particularly the latter. Apart from the founders, an unusually talented group of individuals participated in the success of Calco. They included: Victor L. King, whose dexterity as a Ph.D. student had contributed to the Nobel Prize-winning research of Alfred Werner; organic chemists and pharmaceutical pioneers Moses L. Crossley, Elmore H. Northey, and Martin E. Hultquist; polymer expert Roy H. Kienle; instrument specialist Edwin I. Stearns; and various academics, including R. Norris Shreve, who came with one of the first Calco acquisitions, but remained a consultant after he embarked on his distinguished teaching career at Purdue University. There were also the businessmen, particularly the Klipsteins, and August Merz, former agent for German dyes.

Divisional general managers, later called presidents, receive their fair share of mention here, as do the departmental managers and senior scientists who contribute much to this story. It is from them that we learn about successes—and failures—in discovery, invention, and innovation. The reminiscences of several who worked at Bound Brook from 1940 on, often obtained firsthand through interviews in person, by telephone, or electronic mail, are just as important as the ad hoc mixture of available primary source material, and sometimes more so. In particular, their often different opinions concerning how the site was run since the 1960s give rise to ambiguities that make compelling reading, in part because such views are not confined to this site, or corporation, alone. Some profess that there were problems of management, and not of chemistry and technology; others that management had to decide on a strategy for survival that inevitably meant casting aside dyes and rubber products.

While overall the Calco–American Cyanamid story is certainly one of success, mirroring the remarkable, and justifiably proud, rise of the U.S. dyestuff and organic chemicals industry, some failures were almost monumental, such as the aborted attempt to manufacture anthraquinone from naphthoquinone, and certain aspects of latter-day modernization that led directly to decline. There were also logistical problems, particularly organizational breakdown in communication and lack of motivation among R&D chemists, which plagued Bound Brook and indeed most divisions of American Cyanamid in the 1970s. The latter was part of a more general worldwide malaise in which, perhaps, individual creativity was sacrificed to often short-term profitability. At the same time, few really exciting discoveries had influenced industrial chemistry since the late 1950s. How this was tackled at American Cyanamid receives close attention here, and invites comparison with DuPont, drawing on the account of research activity provided by Hounshell and Smith.

Of the many factors that contributed to the decline of Bound Brook, some were shared with other firms, both American and West European. While tariff reduction, subsequent heavy competition from imported products, and overproduction took their tolls, a principal cause was the emergence of increasingly stringent environmental regulations, especially after 1970. The dye industry had a notorious history of polluting rivers and contaminating wells and soil, often with non-biodegradable, or what the American Public Health Service called refractory, waste. American Cyanamid Bound Brook was no exception. In the eyes of many observers, Calco had turned the Raritan River from a recreational waterway into an open industrial sewer. For this reason, there is an emphasis here on the industry-specific nature of the waste generated during the manufacture of aromatic products, and the manner in which it impacted the environment, as well as the steps taken to combat that impact.

From around 1930, Calco had come under attack from local and state authorities for using the adjacent Raritan River as a waste sink. In 1940, in response to a New Jersey Department of Health order, Bound Brook opened its first (primary) waste-treatment plant, that neutralized the acidity, and was claimed to reduce the color, of wastewater. An extensive system of lagoons for waste treatment, including equalization and neutralization, and impoundments for solid waste, was laid out. Expansion in manufacture, which meant production of more waste, new regulations, and greater public awareness led to the inauguration of a biological (secondary) treatment plant in 1957. This relied on the action of activated sludge. However, even biological treatment had its limitations, and a 1973 consent order forced the company to develop and install what was probably the world's largest industrial activated-carbon (tertiary) wastewater-treatment plant, which became operational in 1977. American Cyanamid's efforts were certainly exceptional, even if they had to be forced on the firm, which, Bound Brook research chemist Erwin Klingsberg remarks, "had fought tooth and nail every step of the way against the New Jersey Department of Health (and later the Department of Environmental Protection), but once they did something it was a showplace, the state of the art."

Around 1980, several American firms were in the process of cutting back on dye production (sometimes by selling dye-making units), and changing focus altogether, though even here the heritage of R&D based on synthetic dyestuffs was the overriding influence in determining new directions. At American Cyanamid, decline accelerated when management discovered that it had committed technical and strategic errors in pushing forward an expensive modernization program. Despite the installation of the advanced wastewater-treatment plant, and attempts to sell the factory, Bound Brook's dye-making operations finally succumbed in 1980, and pigments two years later. Von observed that it "was the last American company to make some of the major vat dyes, and the last manufacturer in the country of Jade Green, which ceased in 1980." Bound Brook became a branch of Lederle Laboratories, increasingly serving as a warehousing and distribution center. Most operations were closed down in the summer of 1998.

Structure of this Book

The first part of this volume is divided into three sections, each of which spans approximately a quarter of a century, and is formulated along the lines of more conventional, or orthodox, histories of chemical industry. These are followed by two chapters that deal with industrial hygiene and environmental issues and act as a bridge to part 2, and a conclusion.

Part 1 starts with "The Calco Chemical Company: 1915–1939," chapters 1, 2, and 3. This section describes how Calco came into being, and developed in the wake of the protection offered by legislation and within the framework of an expanding economy. It pays particular attention to the process of company acquisitions, the takeover by American Cyanamid, and, in chapter 3, diversification into plastics and pharmaceuticals in the 1930s. Long-lived products at Bound Brook included the intermediates aniline and beta-naphthol (both manufactured from 1915), the black colorant nigrosine (1920), and vat dyes (1930). Calco personalities receive considerable prominence here, though sometimes in proportion to what documentary evidence survives.

There is in chapter 3 some overlap with the second section, "The Calco Chemical Division of American Cyanamid: 1939–1953," chapters 4 and 5, which deals with the impact of World War II on Bound Brook, and the aftermath, particularly the interest in German technology, expansion in research activities, and the changeover from military to civilian economies. The role of industry in wartime is an oft-forgotten epic. All branches of the armed forces relied on the products of chemical industry, where the exertions of individuals on the shop floor were often heroic. Patriotic workers—men and women—drove themselves to exhaustion, and faced hazards quite different to those at the front line. They coaxed and tended the machinery that provided seemingly mundane materials such as Calco's melamine all-weather map laminates, a boon to the fighting man. This section also provides some subsidiary stories connected to the war-torn chemical industries of Europe and American Cyanamid's expansion overseas.

The third section, "The Organic Chemicals Division at Bound Brook: 1954–1982," chapters 6, 7, and 8, deals with the period commencing in 1954, when American Cyanamid created four new divisions, one of which, the Organic Chemicals Division (OCD), was centered around Bound Brook. This lengthy central part incorporates not only a complex business story, but also complicated aspects of decline in both technology and invention. Here are described expansion at Bound Brook; new innovations in dyes and polymers; changes at the site, including new research facilities and reconstruction; the debate over the future; and failed attempts at modernization in two important processes. Chapter 8 deals with R&D after 1950, and particularly the period commencing around 1960 when a lack of clear vision regarding long-term research was accompanied by a two-decade hiatus in completely new innovations. There was at the same time considerable complacency engendered by reliance on profits from existing lines which were once novelties but that had become staple commodities, and on what some saw as a labyrinthine bureaucracy. The R&D policies became chaotic as differences of opinion flowed among marketing managers, R&D managers, research scientists, operations managers, and business development managers. While this situation was symptomatic of the chemical industry everywhere, it had a particularly strong impact on strategic decisions made at American Cyanamid's OCD. The extensive transcripts of correspondence, though packed with minutiae, are deserving of close attention, since they give resonance to other critiques of the way research was conducted in the U.S. chemical industry.[4]

Chapter 9 deals with industrial hygiene, covering the peculiar illnesses associated with aromatic chemicals, the Medical Department, and knowledge and growing concerns about the toxicity of chemicals. Chapter 10 takes us into the mid-1970s, at a time when it was thought that the new advanced wastewater-treatment plant and ongoing orders from other divisions would together ensure the future of Bound Brook. Part 1 concludes with chapter 11, a summary and discussion of key issues, especially as they relate to the way in which elements of Bound Brook achievements were integrated into American Cyanamid, perhaps of far greater significance than the relative size of the OCD might suggest.

Since the 1970s, the tremendous contributions of the chemical industry to the American economy have been somewhat eclipsed, in the public's perception at least, by concerns over the impact of manufacture on the environment, particularly contamination of surface and subsurface waters and soil (in addition to atmospheric pollution). This contributed to dramatic changes at several venerable firms, including American Cyanamid. It is for this reason that Part 2 is devoted to the main environmental issues: the story of the impact of Calco's activities on the Raritan River, chapter 12; the advanced wastewater-treatment system introduced in response to legislative and regulatory pressures, chapters 13 and 14; and waste impoundments and soil and groundwater contamination at the site, and the inevitable issues raised by environmental activists, chapter 15. This includes extensive coverage of the actions of the New Jersey Department of Health (from 1970, Department of Environmental Protection). American Cyanamid's final response, the advanced wastewater-treatment plant, serves as a case study for the industry in general.

Following issuance of regulatory directives for cleanup of contaminated soil and groundwater at the Bound Brook site, American Cyanamid engaged in extensive litigation with its insurance carriers, claiming remediation costs under the terms of its policies. The lawsuit was finally settled out of court in February 2000. The comprehensive historical survey, with much fine detail of negotiations with state authorities, does not, however, in any way negate the important role the company played in improving material well-being, and enlarging the range of lifesaving products. Chapter 16 provides a conclusion to Part 2.

Among the material held in archival collections consulted were: the papers of Victor L. King, Dartmouth College Library; documents and reports at Bound Brook Memorial Library; and publications and images at the Sidney M. Edelstein Center and Sidney M. Edelstein Library. Extensive use has been made of American Cyanamid-sponsored material, including Haynes's unpublished and incomplete history of the corporation (1957), *Dyes Made in America* (1940), and articles in the Bound Brook facility's newspaper *Calco Diamond* (first published in 1935), and its successor, *Bound Brook Diamond*. During the first year of its publication the *Calco Diamond* included a valuable ten-part history of Calco's early years. Feature articles in the *Diamond* provided important details about the World War II period and the subsequent two decades. The diamond jubilee of American Cyanamid in 1957 and of Calco in 1965 saw special enlarged issues of the *Diamond* with much historical detail and useful anecdotes. Also invaluable have been American Cyanamid trade catalogs, press releases, correspondence, memos, internal reports, in-house newsletters, articles, and other publications.

While there are gaps, since source material on chemical industry is invariably problematic, and at best fragmented, there is certainly sufficient information from which to prepare a reasonably complete history, one that fills another void in the historiography of chemical technology. Every effort has been made to verify accuracy, establish objectivity, and to separate reporting from opinion, bearing in mind that, understandably, advertising and promotional copywriters tend to emphasize the achievements of their clients while ignoring similar developments at other firms. Particularly useful have been images made by Fairchild Aerial Surveys. Apart from their great value in providing impressions of the sheer size of the Bound Brook facility, these have revealed, for example, inconsistencies in published construction dates for buildings erected around 1940.

Much of this tract has a strong descriptive thrust, and allows Bound Brook personnel to act as frequent narrators through their papers, writings, reminiscences, and, sometimes, interviews and correspondence with me. The inclusion of what might seem to be a clutter of transcripts and digressions on technical points in some sections is occasioned by the extreme rarity of historical resource material on the early modern American chemical industry in general and the dye industry in particular. Deliberate or accidental destruction of company records has in the past been endemic. It took place for a number of reasons, including storage considerations, fires and explosions, flooding, bankruptcy, change of ownership, and concerns over antitrust and environmental lawsuits.

Historical facts not based on original archival sources often have a tendency to become embellished, exaggerated, and distorted. Despite any failings that this may entail, there is no doubt that the clearest and simplest way to give the reader an impression of how the Bound Brook facility functioned is to quote, sometimes extensively, from surviving documents, correspondence, and transcripts of interviews. These are the most accurate records of attitudes, opinions, and even biases, not to mention achievements and failures, technical or otherwise. They also provide a sense of immediacy to the narrative. Chapters 1, 4, and 8 in Part 1 contain extracts from diverse unpublished documents that, woven together, shed light on how the American chemical industry—through a single representative facility—operated for over six decades. What makes them all the more interesting is the fact that they balance information gleaned from the vehicles of corporate communication, such as the very valuable in-house publications. I have tampered with transcripts only to correct errors, factual and grammatical, but no more than is necessary, and certainly with no change in emphasis.

The use of "Divisions" and "Departments" requires explanation. From early on, Bound Brook manufacturing operations were separated into what were originally called divisions, each indicated by a letter, such as Division A, that dealt with intermediates. With diversification during the 1930s, new divisions were added, such as

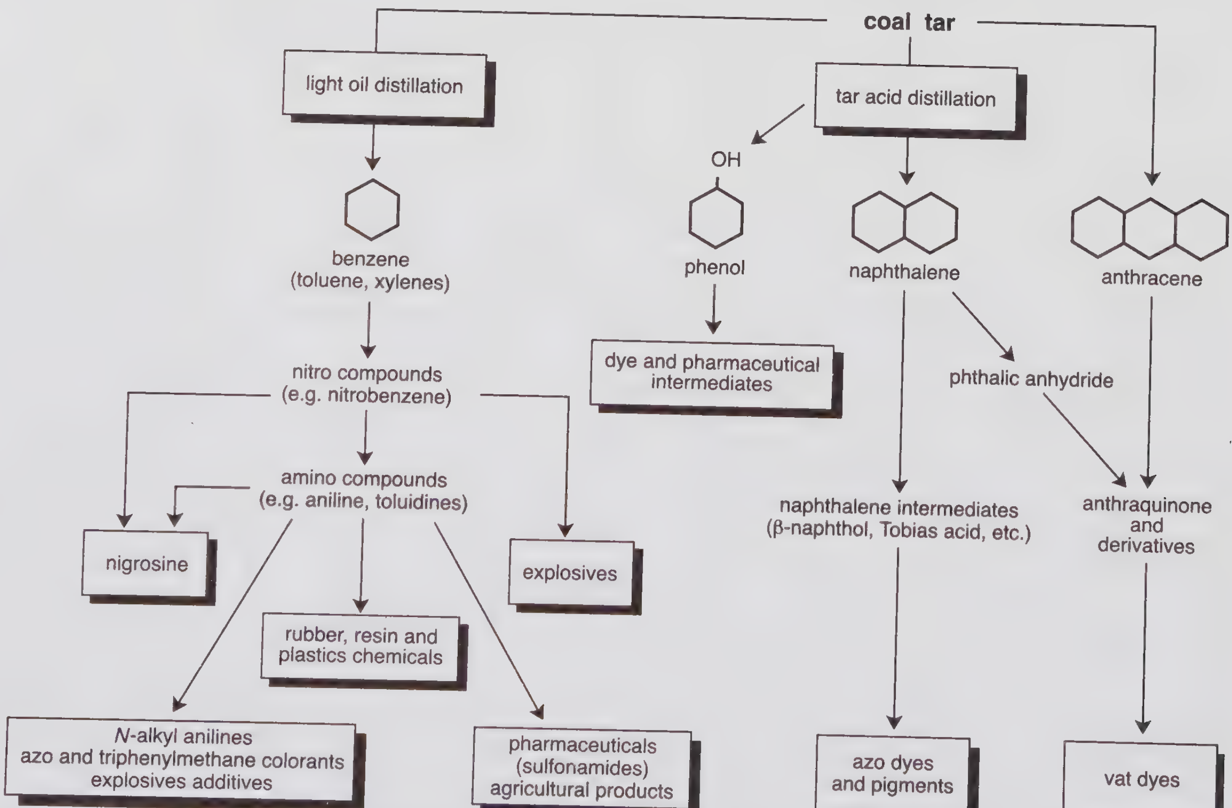
Division P, pharmaceuticals. Divisions were renamed departments after 1939, when American Cyanamid created its Calco Chemical Division. Reorganization in 1954 led to the creation of new divisions, including OCD, with, at each facility, departments. Former OCD president Gerard (Jerry) Forlenza points out that DuPont used the opposite system of naming. For example, in 1931 there were ten manufacturing departments at DuPont. Isaiah Von's summary is worth quoting: "A Cyanamid Division, at least from the '30s on, was like a separate company ... this was true until 1954 when the management started to become more centralized. The Calco Chemical Division was certainly locally run except for capital matters. Departments were more loosely defined, usually one product line or one function. Departments could exist at several levels, for example, one department reporting to another. In 1954, Calco was split into OCD and Pigments Divisions, and remained so until their ends. Later on divisions came and went as the business diversified, expanded and contracted ... beginning in 1954 the divisions became a little less independent as centralized management grew. Also as the company grew older reorganizations became more and more frequent." Von also points out that even in later years manufacturing departments were sometimes referred to as divisions, though to avoid confusion here they have, as necessary, been differentiated, including in quotations. The same situation arose within American Cyanamid laboratories, R&D divisions, and service units. In 1958, Robert G. Krupp, Bound Brook assistant librarian, when referring mainly to the Stamford laboratories in American Cyanamid's in-house *Research Division News*, noted that according to "present-day practice, all of the above 'Divisions,' 'Laboratories,' and 'Units' would be named as 'Departments.'"[5]

In the naming of chemicals, for which there are often various synonyms, those commonly used in the industry, as well as in earlier publications, are retained. Where the prefixes ortho-, meta-, and para- are hyphenated, they are here shown in italic, as is the usual convention. Thus *para*-nitroaniline, but not pararosaniline. In the text I have used the prefixes alpha- and beta-, which mean the 1- and 2-positions of carbon atoms in aromatic compounds discussed here, rather than Greek symbols. More systematic nomenclature is also introduced where appropriate. In many cases the abbreviations adopted at Bound Brook are used. Apart from proper names, such as Meldola's blue and Bismarck brown, capital letters in dye and pigment names are used only where important products associated with Bound Brook are referred to, such as Jade Green (even though this name is not restricted to the Calco/American Cyanamid colorant).

Part 2 makes even greater use of diverse, though more recent, transcripts, taken from sources that include the New Jersey Department of Health, later Department of Environmental Protection (NJDEP), and the Environmental Protection Agency (EPA). Fortunately, state and federal agencies keep on file permit applications, reports of inspections by public health technicians and scientists, affidavits, records of court hearings, correspondence with firms, and other documents. The archives of the NJDEP are held with the New Jersey State Archives, Department of State, at Trenton, while the archives of EPA Region 2, which includes New Jersey, are held at Newark. The National Archives and Records Administration, College Park, Maryland, also holds important source material. Transcripts of NJDEP documents used in this study are not necessarily from these collections. Websites, such as those of the EPA, and various New Jersey agencies, organizations, and citizen's groups, the Water Environment Federation, and corporations involved in environment-related businesses, were particularly valuable sources.

I have used published secondary sources that I believe to be reliable for biographical and other information, introducing corrections wherever possible. Electronic searches have turned up much biographical information, generally found in obituaries, adding to what is available elsewhere. Most Calco and American Cyanamid trade publications will not be found in the Library of Congress. However, a number are available at the New York Public Library. This is an important repository, since much Bound Brook material, particularly internal reports, was lost in periodic floods at the factory. Historian Herbert T. Pratt has built up a collection of Calco Technical Bulletins, now deposited with Chemical Heritage Foundation, Philadelphia. The Bound Brook Memorial Library holds a number of internal documents concerning research into dyestuffs, and the files of Calco research chemist Dr. Neil M. Mackenzie. Invariably, most of the collections used in this study lack detailed indexes, and are not comprehensive.

TYPICAL AROMATIC PRODUCTS
American Cyanamid, Bound Brook, 1915 – 1980



PART 1

"I have talked with managers and chemists in German plants, many of whom have expressed the greatest contempt for our chemical industry, giving a variety of reasons for their contempt, the reasons ranging from the opinion that we were temperamentally unfitted for the chemical industry to saying that we had not the schools to turn out the chemists or the brains to learn the necessary lessons."–Frederick Pope, major, Chemical Warfare Service, United States Army, "Condition of Chemical Plants in Germany," *Dyestuffs: Hearings before the Committee on Ways and Means, House of Representatives*, 66th Cong., 1st. sess., H.R. 2706 and H.R. 649, June 18–20 and July 14–18, 1919 (Washington D.C.: Government Printing Office, 1919), 177.

Section 1

The Calco Chemical Company: 1915–1939

Chapter 1

"At Calco, sticky, smelly coal tars are transformed by the magic of chemistry to brilliant dyes."[1]

"The chief factor in successful dyestuff production is men. From the top of the organization down to the laborers who operate the machines and apparatus success is dependent upon skillful training and technical ability. Processes for the manufacture of intermediates and dyes written out even in considerable detail in textbooks and patents are of little avail to the manufacturer in getting out his goods in the right way, of the right quality, and at the proper cost. He has to have in his organization the proper men, the chemists, the engineers, the foremen, and the laborer who knows how to do the thing in the right way, and these men can only be taught this by actually doing it."–J. Merritt Matthews, "Safeguarding the Dyestuff Industry," *Dyestuffs: Hearings before the Committee on Ways and Means, House of Representatives*, 66th Cong., 1st. sess., H.R. 2706 and H.R. 649, June 18–20 and July 14–18, 1919 (Washington D.C.: Government Printing Office, 1919), 191.

Introduction

This history of the Calco Chemical Company and the people who participated in its management and operation encompasses numerous acquired firms whose manufacturing processes, intermediates, finished products, and markets were major components of the diversification, consolidation, and restructuring that in the 1930s enabled American Cyanamid to become the fourth largest chemical corporation in the United States. While these firms are not neglected here,

AREA OF NORTH JERSEY SECTION

Territory Bounded on the north by the State of New York on the east by the Hackensack Valley, Newark Bay, and New York Bay; on the south by Mercer and Monmouth Counties; and on the west by Hunterdon, Sussex, and Warren Counties.

Map of northern New Jersey, 1944. The bold solid line marks the border of the area covered by the North Jersey Section of the American Chemical Society. It includes Bound Brook, Manville, Somerville, New Brunswick, Sayreville, and Newark. (From "Special Issue, 108th Meeting American Chemical Society, North Jersey Section, September 11 to 15, 1944. Silver Jubilee, New Jersey Chemical Society," *The Indicator* 25, no. 7 [September 1944]: 9. Reproduced with permission of the North Jersey Section, American Chemical Society.)

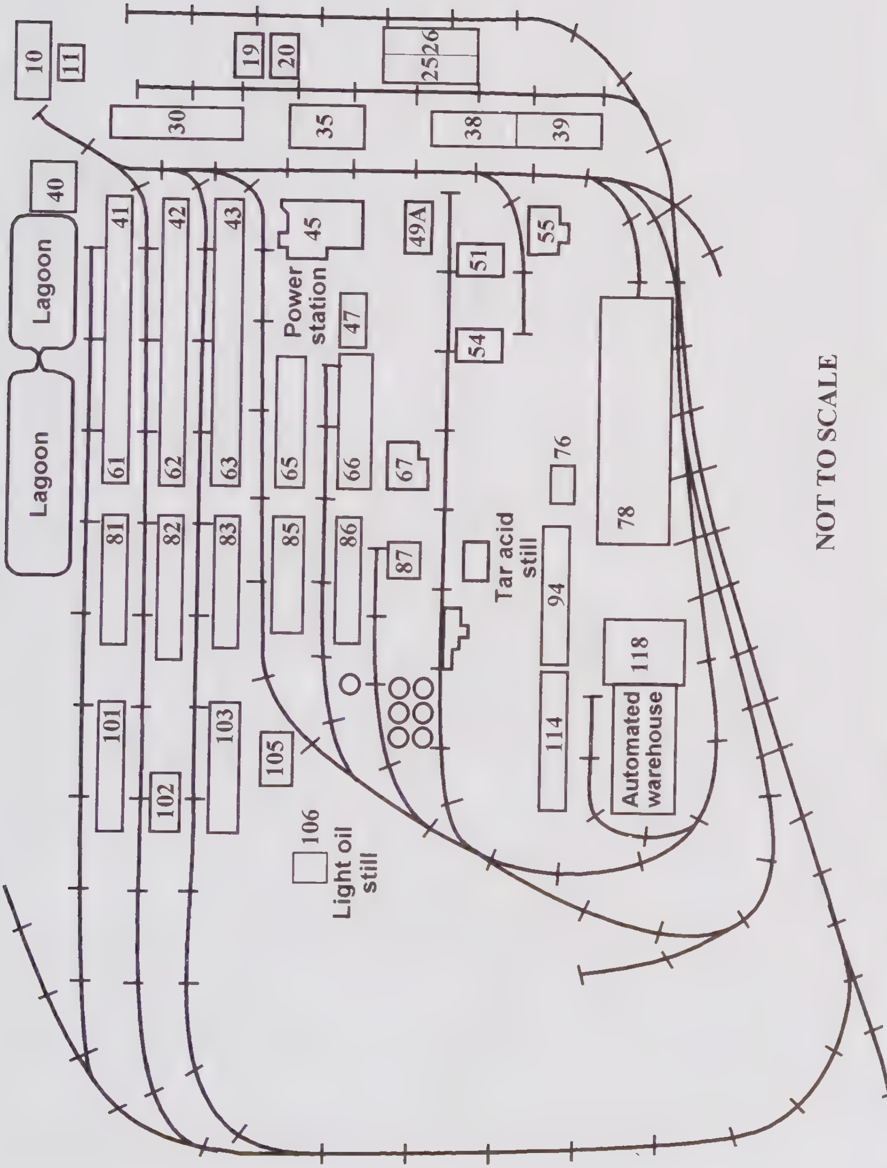
this story is confined mainly to the factory close to, but always known as, Bound Brook, in Somerset County, north-central New Jersey.

Somerset County, created in 1688 and named after Somerset, England, covers 305 square miles (789 square km), and is bordered to the northeast by the Passaic River and to the east in part by the Raritan River and Green Brook. The town of Somerville is the county seat, and nearby is the Duke estate, home of the former tobacco and hydroelectric magnate James Buchanan Duke. The eastern part of the county consists of lowlands that were once inhabited by Delaware Indians, who in 1681 deeded the land to the colonial governor, Philip Carteret. The first European settlers were Dutch, including Colonel Philip van Horne, whose home at one stage during the American Revolution was occupied by cavalry commander Henry Lee.[2] Among the van Horne guests, according to American Cyanamid literature, was General George Washington, accompanied by his wife.

The northern part of the "Garden State" became an important industrial belt not long after the end of the American Civil War. During the 20th century, the many railroads and rivers, and the close proximity to major markets, encouraged numerous chemical and pharmaceutical firms to open manufacturing facilities in New Jersey. As for the Calco Bound Brook factory, which was actually in Bridgewater Township, to the immediate west of Bound Brook, the manufacturing area was located in an angle of land between two railroads, the Central of New Jersey (whose line had opened in 1854) to the north and the Lehigh Valley (connecting with Philadelphia in 1876) to the south. This southeastern section of Bridgewater is just over 30 miles southwest of New York. The original manufacturing area covered 18 acres out of 33 acres purchased in 1915. The Raritan River marked the south and southwest border of much of the company-owned land that eventually reached 602 acres. This included 140 acres to the north, beyond the Central of New Jersey Railroad tracks, known as the Hill Property, on which stood, and still stands, the Van Horne House. The Hill Property became the site of modern application and research laboratories, opened in stages between the late 1940s and 1965. It was also the location of deep production wells, driven to replace those closer to the manufacturing area that had become contaminated by industrial production.

During the early 1940s, when the factory was close to its peak, the main entrance, at the northeast extremity, was approached via an underpass constructed in 1941–42 to avoid direct crossing of the Central of New Jersey Railroad by the 5,000 employees—men and women, including African Americans, Puerto Ricans, and first- and second-generation Italians and East Europeans—then striving to satisfy the needs of America's armed forces and its allies. To the immediate right of the entrance was the new guardhouse, an integral part of building number 40, where pharmaceutical research was carried out (the laboratories were converted to offices after research moved to the Hill Property in the 1950s and 1960s). A few yards to the left was building 10, containing the dye research laboratory, library, and cafeteria. Beyond, laid out in rows, Isaiah Von explains, were "around twenty three-storied manufacturing buildings, some 600 ft. long and 80 ft. wide, covering tremendous floor space, working day and night." Inside these buildings most of the first floors contained a large number of pumps, electrical equipment, dryers, and grinders. In lead- and glass-lined iron and steel reactors, mixtures of chemicals in aqueous and non-aqueous solvents were stirred with the aid of powerful electric motors. In one "shop," the name given to a manufacturing section within a building, ice-making machines on upper floors disgorged their contents into cypress-wood tubs below, where the first stage of azo-dye manufacture took place. Ancillary equipment included plate and frame filters for separating dye from liquid, and blenders. In another shop aniline was converted into the important intermediates (mono)methylaniline (MMA), dimethylaniline (DMA), and ethylaniline, in massive autoclaves. Elsewhere, phthalic anhydride was transformed into anthraquinone and its derivatives, from which vat dyes were made, into phthalein dyes, such as fluorescein, or into phthalocyanine pigments.

In all there were around 140 buildings, including, according to Erwin Klingsberg, various "shacks, sheds, and other big structures," plus distillation columns and batteries of storage tanks. These were connected through wide roadways, a latticework of pipes and other equipment for transfer of chemicals, and several miles of busy railroad sidings. Heavily laden tank cars, boxcars, and gondolas plied their incessant businesses, departing round the clock with vital chemicals that served war industries and contributed to the safety and health of

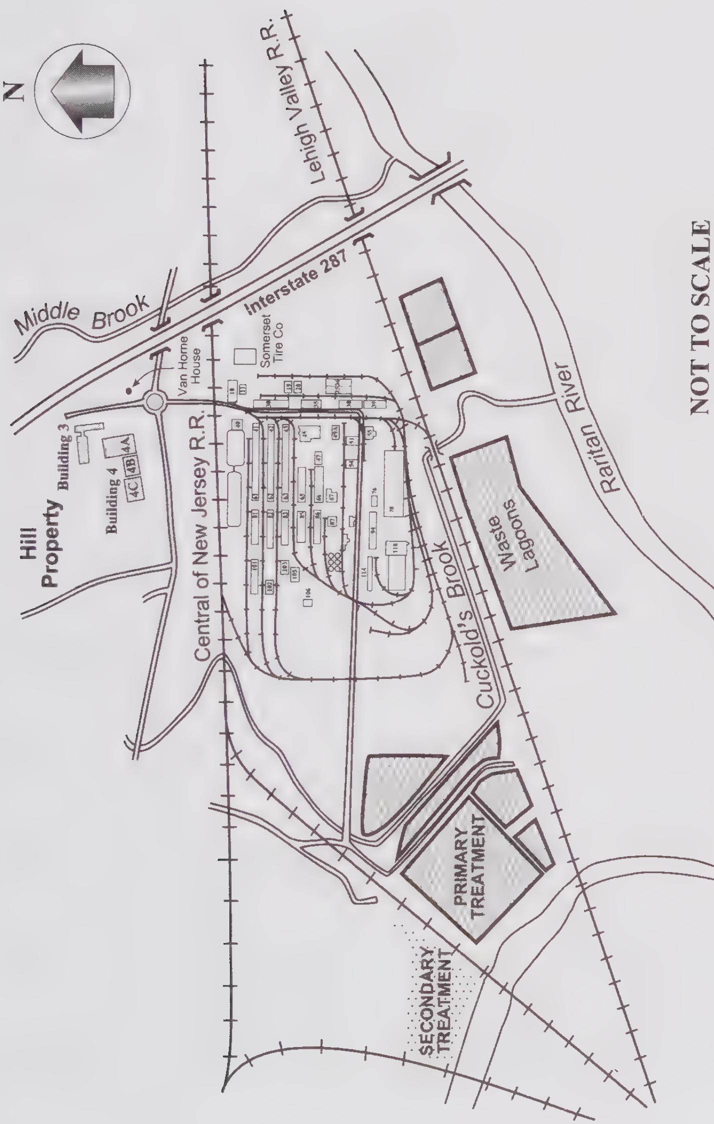


Location of some principal buildings at American Cyanamid, Bound Brook the millions of young men in uniform. To ensure nonstop operation, "Maintenance men roamed the plant on [some forty-five] bicycles ... a coo-coo plant whistle ... served as a paging system."[3]

Between the Central of New Jersey Railroad and the first row of buildings that ran parallel to it were two large lagoons for storage of water for the plant, one, in earlier days, occasionally used as a swimming pool in the hot, dry summer months. In the far distance, to the west, was the main waste storage and treatment area. The plant had its own weather station, part of the installation for control of atmospheric pollution. Each day 10–15 tons of sulfuric acid were used in the manufacture of vat dyes alone, and additional quantities were used to make nitrobenzene, sulfa drugs, rubber chemicals, and various other products. Most of the spent acid entered the effluent stream. Two decades later, in the mid-1960s, the scale of activity was simply staggering:

The plant is so vast, it uses 20 million gallons of river water daily, burns 700 tons of coal a day, manufactures ice for its own use at the rate of 140 tons a day, and purchases, among other things, 35 tons of salt a day ... Its tools range in size and ease of dexterity from a small delicate laboratory scale to a crane with a 100-foot long boom. Even such incongruous sounding aides as a blimp [mobile rubber-tired tank carrier for liquids] and a giraffe [mobile elevator on truck body] are used in the production area. The plant holds 300,000 gallons of water suspended high in the air (in three towers), uses hundreds of miles of piping and 2,500 pumps, [and] is protected by 20,000 sprinkler heads ... Its employees produce one patentable idea a week, a profusion of products as diverse as a resin to protect silk and a pharmaceutical to aid ulcer victims, and are content only when a particular dye has successfully passed hundreds of tests ... This CHEMICAL CITY has a two-engine fire company, a power house supplying enough electricity to serve a community of 30,000 families ... a modern hospital staffed by three medical doctors and a number of nurses, a technical library containing 5,500 volumes, two cafeterias, a fully-equipped maintenance and repair shop, a warehouse, a sewing room, a laundry handling 1,200 tons of work clothing per year, a railroad with two diesel locomotives and 100 railroad cars operating on 12 miles of track, a modern effluent plant, a radio station, a weather measurement station ...

This Chemical City was one of two locations in the State at one time to have the new electron microscope. It has the largest dryer in New Jersey, the

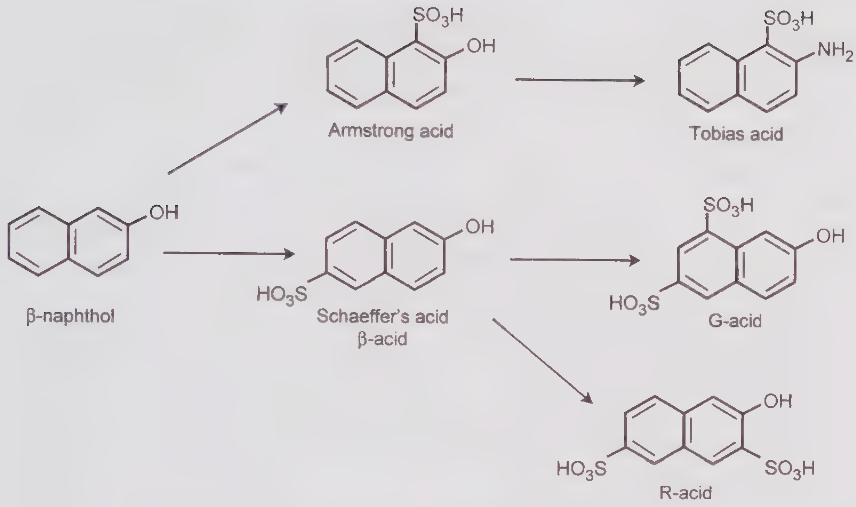


American Cyanamid, Bound Brook facility, Bridgewater Township, Somerset County, New Jersey first foam fire truck purchased by a chemical plant in New Jersey, and the first Boy Scout Explorer Post of its kind in the United States. It is one of the largest producers of sulfa drugs and catalytic aniline in the United States ... It produces the most beta naphthol of any source in the U.S. It operates one of the largest biological waste treatment plants in the world, and has the largest laboratory extractor of its kind in the world.[4]

Today, the site is but a fading memory for those surviving chemists who once gave it such vibrancy. Their shared reminiscences, anecdotes, and documents humanize this story of just one fragment, though an important one, of American science-based technology in the 20th century. They include research chemist and administrator Dr. William B. Hardy, research fellow and heterocycle chemist Dr. Erwin Klingsberg, Klingsberg's former boss Dr. Jay Leavitt, vat dye specialist and former head of the Pigments Division's unit at Bound Brook, Dr. Isaiah Von, and Calco's first chemical engineer with a doctorate in this field, C. Marsden Vanderwaart. They all joined Bound Brook between 1940 and 1946, and each was associated with the factory and its laboratories, or with American Cyanamid, for over three decades.

The land where American Cyanamid's Calco Chemical Division once stood is now bordered by highway Route 28 to the north and Interstate 287 (opened in the 1960s) and Somerset Tire Service (previously a Sherwin-Williams factory) to the east. Until the end of the 1970s, the facility was a major producer of synthetic, or "coal-tar," dyestuffs, pharmaceutical products, and intermediates and ingredients for tires and polymers. The range of products had been enlarged from around 1930 through acquisitions of chemical companies, many engaged in dye manufacture. While not all organic chemical production was moved to Bound Brook, the satellite operations did rely to varying extents on intermediates and products manufactured and invented at Bound Brook. Coal-tar aromatic, and, later, petroleum-derived aliphatic and aromatic, intermediates invented and produced at Bound Brook were sold to various other chemical concerns.

Coal-tar organic compounds are based on specific types of ring molecules, mainly hydrocarbons, containing carbon and hydrogen. The simplest of these coal-tar aromatic hydrocarbons is benzene, and other examples are toluene and naphthalene. They were converted



Conversion of β-naphthol to sulfonic acid derivatives

into intermediates, including the nitro compound nitrobenzene, the amino compounds aniline, the toluidines, dimethylaniline, and benzidine, and phenolic compounds such as beta-naphthol. The latter was the starting point for naphthalene derivatives with strange names that made sense only to the brotherhood of chemists familiar with aromatic chemicals. The names included Tobias acid (2-amino-1-naphthalenesulfonic acid), Armstrong acid, Schaeffer's acid, and R- and G-acids (and their salts).

The intermediates were converted into dyes, sometimes in several steps, that is, via other intermediates. Some intermediates were the sources of 20 or more dyes. This is one of the most distinctive features of dye manufacture; many quite complex products can be made from a limited number of intermediates. The final stages were carried out on a much smaller scale than those used to produce the principal intermediates. Except for modifications to dyes, often for special applications, there were few major changes from the 1940s (and in some cases from the 1920s) until the late 1950s, when fiber-reactive dyes, those that form chemical bonds between dye and fabric, were introduced. The modified dyes included those suited to synthetic fibers, such as nylon, polyester, and acrylics. There were also special-purpose dyes, such as that used to turn the ripe, green Florida oranges a color more in keeping with the name of the citrus fruit.

Of the three main classes of dyes produced at Bound Brook, two were made from amino compounds, those containing the atomic grouping of one nitrogen and two hydrogen atoms. These were azo and triphenylmethane (more correctly triarylmethane) dyes, that dated from the 1860s and 1870s. The third main class was comprised of the anthraquinone vat dyes, derived from anthracene, and, in the United States especially, from naphthalene-derived phthalic anhydride and benzene or its derivatives. Many dyes found wide application outside of the textile industry, such as in paper dyeing and gasoline colors. Other Bound Brook dyes, and pigments, collectively known as colorants, were of similar origins. Thus the black nigrosines were prepared from nitrobenzene and aniline; certain sulfur-containing dyes were made by introducing sulfur atoms as bridges between aromatic moieties; and the phthalein dye called fluorescein was prepared by fusion of phthalic anhydride with the phenol called resorcinol. The phthalocyanines, developed in the 1930s by Britain's ICI, were, incidentally, the only completely new structural class of dye introduced in the 20th century. (ICI, or Imperial Chemical Industries, was established in 1926 through the merger of British Dyestuffs Corporation, alkali manufacturers Brunner, Mond and United Alkali, and Nobel Industries Ltd.)

By World War I a number of coal-tar dyes were known to have antiseptic properties, and became known as medicinal dyes. From the late 1930s, coal-tar dye intermediates were employed in the manufacture of sulfa or sulfonamide drugs. Bound Brook, through its aromatic intermediates and collaboration with American Cyanamid's Lederle unit, became associated with the leading American developments in sulfa drugs. Moreover, some of the Bound Brook coal-tar compounds, such as aniline, were also widely used in the rubber-processing industry, particularly for tires, and others were essential in the production of polymers. Bound Brook was the first site of commercial manufacture of melamine resins used in such familiar products as Formica. Bound Brook produced other modern plastics and resins, notably from toluidine-derived diisocyanates that were converted into polyurethanes, including the spandex fiber known as Numa, and acrylonitrile-based acrylic fiber, particularly Creslan, named after the American Cyanamid inventor Arthur Creslan. These were direct, and indirect, outcomes of a century of research into synthetic dyes and nitrogen products.

Synthetic Dyes and the Nitrogen Industry

There are many competent accounts of the origins of the synthetic dye industry, including one presented by former Bound Brook research chemist Hans Z. Lecher during the 1956 Perkin Centennial celebrations held at the Waldorf Astoria Hotel in New York. In 1856, William Henry Perkin, teenaged student of the German chemist August Wilhelm Hofmann at the Royal College of Chemistry in London, discovered the first "aniline" dye at his home during the Easter vacation. His product was synthesized in three steps, starting with coal-tar benzene. The benzene was converted into nitrobenzene, which was then reduced to afford aniline, the intermediate from which, by treatment with an oxidizing agent, a brilliant purple dye was produced.

Perkin and his family opened a factory to manufacture the aniline dye, soon known as mauve. In 1859, an aniline red was discovered, also by treating aniline with an oxidizing agent. The red colorant was known as fuchsine in France and magenta in England, and Hofmann gave its free base the scientific name rosaniline. The red reaction worked because amino compounds of toluene, the toluidines, were present in the commercial aniline. In 1861, aniline red was converted into aniline blue, and in 1863 the red was transformed into a range of violet dyes known as Hofmann's violets. In the meantime, an aniline black colorant was isolated from the residue of a mauve process developed by the German chemical inventor Heinrich Caro, then working in Manchester.

At first the industry was based mainly in England and France, though the new discoveries were quickly copied in Germany and Switzerland. The outcomes of patent litigation led to the decline of the British and French industries, and, because of the absence of a comprehensive patent system in the German states, assisted the growth of the German dye industry. Patent suits and environmental difficulties did, however, encourage new ways of making aniline dyes. Thus from 1866, the hydrogen atoms of the amino group in aniline were replaced in industrial processes by alkylation and phenylation to provide intermediates, the *N*-alkylated and *N*-phenylated anilines, respectively. (The italic *N*- indicates that a group of atoms has replaced a hydrogen attached to nitrogen in the amino group of aniline. In common usage the *N*- and *N,N*-, the latter showing that the two amino hydrogens are replaced, are often left out of the names.) These intermediates enabled the circumvention of patent monopolies, since they could be converted directly into violets and blues, respectively. The processes also avoided the use of arsenic acid, the main oxidant used to prepare aniline red, the original intermediate from which the blues and violets were obtained. Severe environmental problems arising from the use of arsenic acid brought about its replacement by nitrobenzene, which led to the discovery of the black colorant called nigrosine. From 1865, the industry that had originated in England, and flourished for a time in France, moved to Germany.

Badische Anilin- & Soda-Fabrik, better known as BASF, was founded in 1865 in Mannheim, Baden, to manufacture aniline red and its derivatives, as well as other coal-tar dyes. Heinrich Caro returned to Germany from England at the end of 1866 and acted as a consultant to BASF, before joining that firm in 1868. It had relocated to Ludwigshafen, on the west bank of the River Rhine, and the river served as both a waste sink and a means of transport for raw materials and finished products. Early in 1869, Caro became involved in industrialization of a process for synthetic alizarin, the commercially important colorant previously obtained from the root of the madder plant. The starting point was coal-tar anthracene, which was converted into anthraquinone, followed by sulfonation, then fusion with alkali under pressure to afford alizarin, as well as various coproducts, some that also became commercial dyes.

During the mid-1870s, Caro developed azo dyes, such as chrysoidine, and similar products he had worked with in Manchester, such as Bismarck brown and induline. These were based on coal-tar-derived amino compounds. German chemists established the constitutions and structures of many of these compounds, including, in 1878, the early aniline dyes. The latter were found to be triarylmethane derivatives, and once this was known numerous new products became possible. The *N*-substituted anilines became important intermediates in the manufacture of both triarylmethane and azo dyes. In 1884, azo dyes based on the aromatic intermediate benzidine were invented. These were the first synthetic dyes that adhered to fabrics without the need for a fixing agent (mordant). For this reason they were known as direct or substantive dyes. Another class of dye was the phthalein type, which included fluorescein and Caro's eosin, or brominated fluorescein (1874).

Caro also introduced the industrial research laboratory as a formal business unit at BASF. Eventually, each main operating department had a laboratory that increasingly became the domain of highly qualified chemists, who engaged in research, analysis, and process development. Academic consultants, particularly Adolf Baeyer, played important roles as inventors for BASF and other German firms. At the end of the 1880s, Caro oversaw the construction of a central research laboratory at Ludwigshafen. Its purpose was to deal with research and development (R&D), and the protection of BASF patents. Later, the departmental research laboratories became the more active sites of discovery and invention, often because they were more closely connected to particular types of products and end uses, and also because they were sometimes better able to foster new directions and diversification. The latter included, at BASF, nitrogen products, high-pressure processes, and synthetic rubber. This set a pattern that was closely followed in all science-based chemical and pharmaceutical industries until the 1960s, including at Bound Brook. When the laboratory landscape did change dramatically in the 1960s, it was with the widespread introduction of instrumentation, a transformation started by chemists and physicists at American Cyanamid, originally at Bound Brook, and later at Stamford.

In 1897, BASF and Hoechst in Germany were the first firms to manufacture synthetic indigo. Four years later, René Bohn at BASF applied the indigo reaction conditions to an anthraquinone derivative and discovered the first of the anthraquinone (more correctly anthraquinonoid) vat dyes, also known as indanthrene dyes. With this innovation, three types of anthraquinone dyes became available: mordant (such as alizarin); acid (R. E. Schmidt at the German Bayer firm, 1894), and vat. Throughout much of the 20th century, dye manufacture, particularly at Calco, was generally dominated by azo and vat dyes. The market for the relatively expensive vat dyes, noted for their resistance to fading under strong sunlight, was far greater in the United States than in Europe.

Toward the end of the 19th century, the German dye industry embarked on diversification based on its coal-tar intermediates. These became important medicinal products, including the Bayer company's aspirin, which was made from the intermediate salicylic acid (*ortho*-hydroxybenzoic acid). Dyes were also used as models for products that attacked sites of infection within the body. The first major success in this direction was Paul Ehrlich's arsenic-containing analog of an azo dye (the product was actually far more complex), known as Salvarsan, marketed by Hoechst in 1909. Some colorants, the medicinal dyes, were used extensively during World War I as antiseptics. In the 1930s the curative action of a bright red azo dye led to the discovery of the first sulfonamide, or sulfa, drug at Bayer, then part of I.G. Farben (the 1925 merger of BASF, Bayer, Hoechst, and AGFA). Calco became the American pioneer in the development and production of sulfa drugs.

In many respects, and mainly as a result of progress in the dye industry, organic chemistry during the first decades of the 20th century reached a stage of development comparable to molecular biology at the beginning of the 21st century, including through extensive academic–industrial relationships. In 1900, the list of known organic compounds, including their properties and structures, was enormous, and they could be reproduced using standard techniques. The mechanisms of the transformations, however, were unknown, and many gaps remained to be filled. For dyes, there was great interest in the connection between structure and function. Today there is a similarity between the human genome project and organic chemistry around 1900 in that there is an almost complete knowledge of the nucleotide sequence, but very little is known about gene functions (and even less about possibilities for curing genetic diseases). Major questions of the applied life sciences concerning protein structure and how proteins carry out cellular functions—structural bioinformatics—were among those addressed by American Cyanamid researchers from the 1980s.

BASF, unlike Bayer and Hoechst, did not pursue the organic chemistry-based pharmaceutical business but concentrated its diversification efforts on an important area of inorganic chemistry, nitrogen fixation. Nitrogen products were essential fertilizers and were also important in the production of the new explosives, such as TNT (trinitrotoluene), based on coal-tar intermediates. Electrochemistry, for which there were a number of industrial successes in the 1890s, offered possibilities for trapping atmospheric nitrogen as its oxide, as investigated at BASF and elsewhere. In the early 1900s, BASF was attracted to an alternative approach based on the high-pressure combination of hydrogen with nitrogen to form ammonia. This was developed successfully by the academic chemist Fritz Haber through bench-scale experiments in his Karlsruhe laboratory (1909), and then by Carl Bosch at BASF on a pilot-plant scale. In 1913, BASF opened the first synthetic ammonia factory. The Haber–Bosch process became critical during World War I for the supply of Germany's essential nitrogen products. The level of scientific and technical sophistication was such that none of the Allied countries managed to replicate BASF's ammonia process. From world leader in dye invention and innovation, BASF had become world leader in nitrogen and high-pressure chemistry.

One of the nitrogen-fixation processes based on electrochemistry did succeed. This was the cyanamide process—the combination of nitrogen with calcium carbide—invented in Germany by Adolph Frank and Nikodemus Caro (a distant relative of Heinrich Caro) in the early 1900s. Its economic viability depended on cheap electricity, which meant hydroelectricity. Therein lay the origins of the American Cyanamid Company in 1907. Thus whereas BASF started out with coal-tar dyes and diversified into nitrogen products, American Cyanamid started out with nitrogen fixation and diversified into dyes and other products based on coal-tar intermediates.[5]

Calco and War in Europe

The origins of the Calco Chemical Company can be found in the textile manufacturing company Cott-A-Lap, established in New Haven, Connecticut, in 1900 by E. F. Jeffcott to manufacture high-grade burlap wall-covering fabrics.[6] Williams Haynes explained the market for this product:

> Only one of the oldest generation now remembers the plush and gilt era when the last word in wall decoration for the hallway, dining room, and especially for Papa's den, was burlap ... [Cott-A-Lap] drew their own designs, dyed the burlap themselves, and were proud of turning out superior products. Dealing in luxury wares, sold at fancy prices in the good old pre-income tax days, the business, though limited, was profitable.[7]

The jute for burlap was grown in India, processed into cloth in Scotland, and then, at Cott-A-Lap, dyed and treated with the coal-tar intermediate beta-naphthol, which prevented mold formation. The Yale-educated Robert C. Jeffcott (1876–1961), son of the founder, had worked briefly at the General Electric Company, an early research-based firm, before joining Cott-A-Lap. It was at his suggestion that burlap manufacture be taken up closer to the two main sources of consumption, New York and Philadelphia. The outcome was a new factory, located at Somerville, New Jersey, opened in 1909. However, it ran into difficulties when war broke out in Europe during 1914. The supply of jute from Britain was cut off, since burlap was required for sandbags. More important, dyes were also in short supply. The United States possessed around seven manufacturers of synthetic dyes, none of great significance; the extensive textile industry relied on imports of foreign, mainly German, synthetic dyes. This latter source was reduced to a trickle as a result of restrictions on exports from Germany and the British blockade on transatlantic German merchant shipping. The last German-made dyes arrived in the United States through normal channels at the end of April 1915.[8] It was time for Cott-A-Lap to diversify into the then high-tech world of aromatic dye chemistry.

As a first step, the Cott-A-Lap directors decided to embark on manufacture of coal-tar dye intermediates produced from benzene and naphthalene. The financial incentive lay in the fact that the price of products such as coal-tar aniline and beta-naphthol had increased dramatically, and continued to do so, "beta naphthol from 8 cents to 75 cents [per gallon]; aniline oil from 10 cents to $1.35."[9] Cott-A-Lap certainly had the advantage of familiarity with dyes and their use, as well as with the important intermediate beta-naphthol, from which many azo dyes were made. The management, however, had to find out how the hydrocarbons were converted into the sellable intermediates, as well as dyes. In this they were aided by "several German textbooks on the subject" and with "the beginnings of a laboratory they called upon a professor of organic chemistry at Yale for consulting advice." The professor was Dr. Treat B. Johnson, former classmate of Jeffcott at Yale.[10]

One of the first qualified chemists to join the new venture in 1915 was 38-year-old Alling Pridden Beardsley, who had obtained his Ph.D. at Yale in 1902, and then joined the New Haven Gas Light Co., Connecticut, where he became chief chemist. Lighting gas was produced by distillation of coal. The process left coal tar as a residue. Certainly this would have provided plenty of familiarity with the raw material from which dye intermediates were synthesized. The first Cott-A-Lap products, made in a shed at the Somerville site, were the intermediates aniline and beta-naphthol. Soon there were plans for expansion. This brought objections from the residents of Somerville. The nuisances—solid, liquid, and gaseous releases—from manufacture of insalubrious coal-tar products aroused the ire of the "City Fathers of Somerville [who] put their foot down on any expansions of such a hazardous and odoriferous industry in their midst."[11] Haynes mentioned that after a permit for building extensions was refused: "This ultimatum reopened the divided opinion of the Cott-A-Lap directors ... they agreed to disagree. Those in favor of continuing the dye-making venture undertook to back the project personally and independently."[12]

Disagreements, however, were soon resolved. A more isolated spot in New Jersey was sought out and in spring 1915 the younger Jeffcott and partners purchased 33 acres of farmland at Bridgewater, near Bound Brook, and close to the Raritan River. The next step was to create a subsidiary company to manufacture products from coal tar.

> Jeffcott's bold idea prevailed, and on June 28, 1915, the Board authorized the organization of a company with 500 shares of stock, par value $100 each, "to begin the manufacture of chemicals and dyes ... And be it further resolved, that the Cott-A-Lap Company subscribe for sufficient of the authorized capital stock to finance this business in amount at this time not in excess of $15,000."[13]

This was announced to Cott-A-Lap stockholders on June 30, 1915, by Robert Jeffcott, vice president and manager:

We shall accordingly cause to be incorporated a small company (of which this company will own the entire stock) for the purpose of manufacturing chemicals, some dye stuffs and other allied products. It is not the intention to manufacture war materials; but to make some of the products which have advanced so tremendously in market value, owing to their importation from Germany having been stopped. Should the present values last this new field should be extremely profitable, but even should conditions change it is the expectation that an eminently satisfactory business in that direction can be developed for peace times and permanently ... After mature deliberation it was, therefore, decided advisable to purchase land sufficient to take care of the growth of this business for a long time to come and accordingly there was purchased a tract of land of about thirty-three acres between Somerville and Bound Brook, lying between the Central Railroad of New Jersey and Lehigh Valley Railroad and extending beyond the latter to the Raritan River. On this site there are now being constructed three 80 x 40 buildings for the chemical work.[14]

The name of the wholly owned subsidiary was Calco Chemical Company, derived from Cott-*A*-*L*ap *Co*. (Calco was also the name of the firm's highest grade of burlap.) Jeffcott was appointed president of Calco, a post he would hold until 1939. The Calco Chemical site was chosen in part because it was conveniently served by the two railroads. Connections with the Central of New Jersey were laid down in July 1915, and with the Lehigh Valley in June 1916. Immediately to the east was the new insecticide works of Frank Hemingway & Co., opened in 1913 (and from 1919 owned by the paint and pigment manufacturer Sherwin-Williams, founded in 1870 as Sherwin, Williams & Co., in Cleveland). A stream known as Cuckold's Brook formed the western border of the property and flowed into the Raritan River, the sink for liquid waste, and later a major source of water for the factory. Johnson remained as consultant, and in this capacity recommended chemists to the Calco management.[15]

The first buildings, then known as 1, 2, and 3, were erected by the autumn of 1915 (they were later renumbered 11, 12, and 13, respectively). Two-story building 1 contained at the ground floor level the office, a combination library and conference room, dormitory, kitchen, and temporary dining room. A laboratory and storage area for raw and finished materials occupied the upper floor. Buildings 2 and 3 were of one-and-a-half stories, and identical. Building 2 served for the production of beta-naphthol, and as the stockroom. Building 3 was for nitration of benzene to nitrobenzene (oil of mirbane) and its reduction to aniline oil; two small nitrators (kettles, or reactors) and two reducers (kettles) were installed for these purposes. The first nitrators were 42 inches in diameter and 30 inches high, and little different from similar equipment used in Europe since the 1860s. Two locomotive-type stationery boilers located south of building 3 supplied steam, and a deep well provided water for the facility to a tower whose tank bore the company's name.

Longtime Calco employee John H. McMurray wrote the history of the early years of Calco on which the above description is based, and is a highly reliable source.[16] By contrast, Haynes's unfinished history of American Cyanamid, while particularly helpful in explaining the genesis of Calco and of certain of its products, suffers from time compression and some confusion. His description of Somerville is actually that of Bound Brook, but is useful for the detail:

> They built a little plant, three small buildings, and went to work learning the theory of coal-tar chemistry and the practice of making coal-tar intermediates. Their teachers were [Hans T.] Bucherer's textbook, *Lehrbuch der Farbenchemie* [*Die Teerfarbstoffe mit besonderer Beruecksichtigung der synthetischen Methoden*], supplemented by well-thumbed sets of [Gustav] Schultz's *Farbstofftabellen* and [Paul] Friedländer's *Fortschritte der Theerfarbenfabrikation [und verwandter Industriezweige]* ... They did waste many precious hours in false starts and unnecessary labors, and they did spend needed dollars unwisely; but they did learn organic synthesis thoroughly.
>
> The textbooks are always about ten years behind current chemical plant practice; articles in the technical journals seldom tell all; even the German patents, as everyone learned, never revealed the little tricks of the trade and often omitted steps essential to profitable yields or saleable quality. So the Calco staff had to discover for themselves that invaluable chemical know-how: the right temperatures, the correct pressures, the best time cycle for each step in every operation.[17]

Production of aniline oil and beta-naphthol were soon expanded. In December 1915, the north section of what was the most substantial early building, no. 8 (later no. 30), was started. At first, this housed a maintenance and machine shop, and a stockroom on the second floor. Beta-naphthol manufacture was transferred there in the spring of 1916, and the other activities were soon displaced. After building 8 was extended, azo-dye manufacturing plant was installed in the central part. A baker's oven for drying and a corn grinder for pulverizing were adapted to coal-tar dye intermediate manufacture. Erected immediately to the west of building 8 were a refrigeration building (no. 11) for the ice required to maintain the low temperature in azo-dye reactions, a new boiler house (9), and a transformer station.

The aniline plant in building 3 was completely rebuilt five times in the first two years. The hydrochloride salt of aniline was produced in a "temporary shed" located between buildings 1 and 2. A small sulfanilic acid (aniline with a sulfonic acid group incorporated) plant was installed in the east end of this shed.

In order to gain access to dye products and new markets, in the summer of 1916, Calco acquired the Neidich Process Company of Burlington, New Jersey. This manufacturer of carbon papers and typewriter ribbons had commenced, with limited success, production of the triphenylmethane dye methyl violet and methylene blue, including intermediates such as the dimethylaniline. The purchase included the Burlington, Jersey City and other Neidich facilities. Calco also gained access to a process for salicylic acid, in a plant acquired at Walkerville, Ontario. At Bound Brook, dimethylaniline was manufactured, probably by the Neidich process, in the south end of the, by then, quite sizeable building 8. Calco collected the methanol required for this process from a wood distillation facility at Buffalo, New York. This distillation process was worked until the late 1920s, well after the BASF high-pressure process for synthetic methanol was introduced (in 1923), and the product was imported in bulk into the United States (1925). The wood-derived methanol was invariably contaminated with acetone, which was removed at Bound Brook.

Though the main emphasis was on production of intermediates, Calco now manufactured a few long-known azo and triphenylmethane dyes, including those in which the dimethylaniline was required. The first Bound Brook dyes, in 1916, were of the azo type. Others were made at the Neidich factories.

Water for the Bound Brook facility taken from artesian wells was found to be hard, causing considerable scale formation in the steam boilers. A short-term solution in 1916 was provided by a pipeline that carried water from the Middle Brook, a short distance to the east, across the adjoining Hemmingway & Co. property.

From the start there were many operating difficulties, particularly frequent fires, sometimes in unexpected places. Inexperience with the handling of aromatic chemicals did not help.

> The benzene storage tanks were none too good, and one fire resulted from some benzene seepage into the ground. Several laborers were engaged in making an excavation for the nitrator house [building 3] when, without warning, flames were seen to shoot from one of the holes. The flames ignited the holes and immediately several of them were on fire.[18]

Fires and fumes were routine hazards.

> One of the major problems was that of concentrating spent acid resulting from the nitration operations. The first concentrator built at this plant was located south of Bldg. 3 and consisted of a series of small silica pans arranged in cascade formation. Concentrating with this equipment was a troublesome problem, as the separation of nitrobenzene from spent acid was not always good, with the result that numerous fires added to the difficulties. In the late summer of 1916 a Broome type concentrator was built. It was designed for a capacity of 10 tons per day, but was expensive to maintain and caused considerable fume annoyance.[19]

Some of the first products were of inadequate quality, since the benzene and naphthalene obtained from the distillers of coal tar were of variable quality. Complex intermediates that were turned into other intermediates and dyes had to be pure, or at least of consistent quality. It was not long before it was found necessary to "scrupulously purify [the basic raw materials] ... [Then] out of these standardized crudes produce thoroughly dependable, low-cost intermediates." There were considerable dangers attached to the purification of flammable and troublesome chemicals:

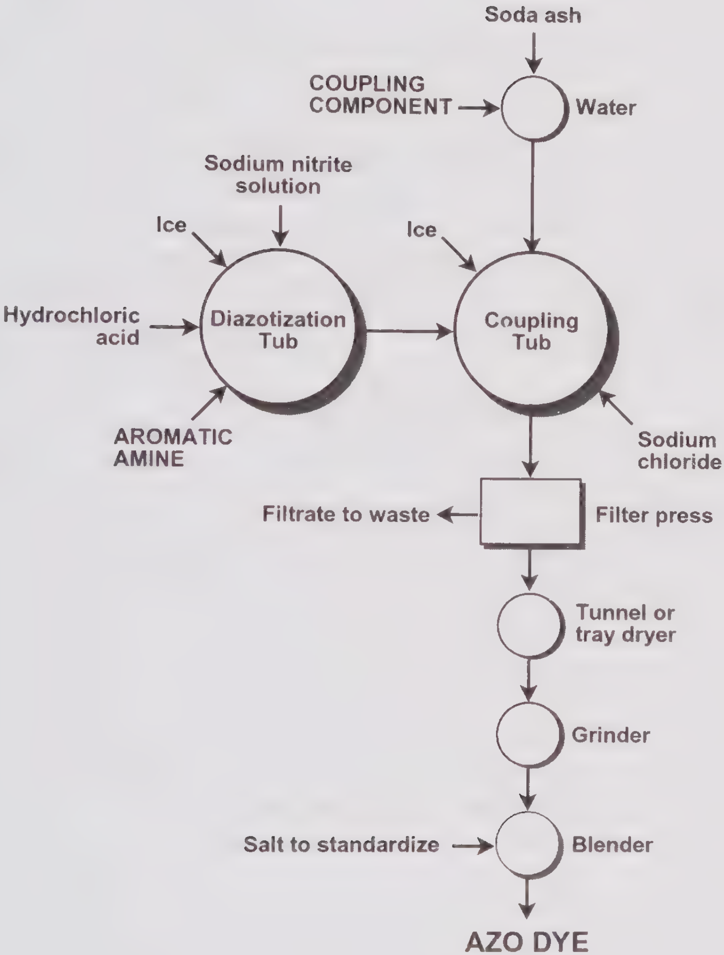
> In the fall [of 1916], it was decided to build a naphthalene sublimer. It was realized, of course, that this was an extreme fire hazard and should be located at

quite some distance from the main plant. The sublimer consisted of a sheet metal building with an oil heated pan in one end. The naphthalene in this pan was heated up and the vapors passed into the sublimer chamber. The plant had been in operation only a few days when it caught fire. It spread and in a few seconds was a roaring furnace. In a matter of minutes the results of weeks of work had been completely destroyed.[20]

Notwithstanding the problems of working with difficult aromatic compounds, Calco soon became the largest U.S. producer of beta-naphthol and aniline oil. By the end of 1916, the sulfonated beta-naphthol intermediates known as R-salt and G-salt were also made. The business was further stimulated at this time when Congress passed the Revenue Act of 1916, which afforded tariff protection to the chemical industry. Calco at Bound Brook and its other facilities stepped up production of dyes, particularly the newly invented metallized chrome dyes, that were required for the dyeing of military uniforms. These were based on Calco's orange, brown, yellow, and green colorants. Another product was the yellow azo dye called tartrazine.

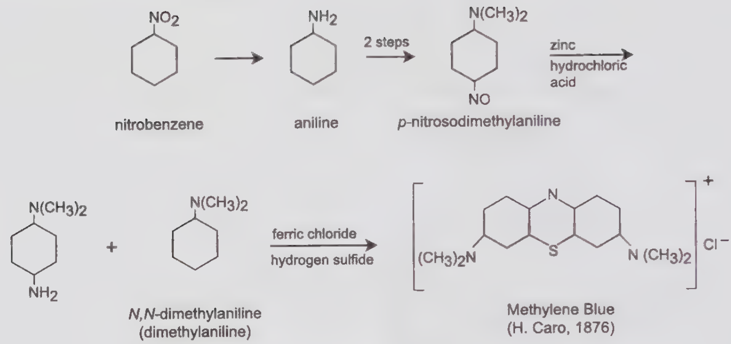
The rapid growth in business made new demands on administration: "Work was, therefore, started in the spring of 1916 on the erection of a new office building [later no. 40] which was located in the field just west of the entrance road. The original building was of brick construction, three stories high, and measured 40′ x 104′. The building was ready for occupancy about December 1, 1916."

The first floor of the office building was occupied by several offices and the drafting room, which having outgrown its limited space in Building No. 1, had temporarily been moved to the northeast corner of Building No. 8. The building at that time appeared to be of very generous proportions. The telephone exchange and reception room was provided at the right of the main entrance. The next office was occupied by Mr. A. H. Smith, who was in charge of insurance, fire protection, engineering, and certain construction work. The northeast corner office was occupied by Dr. Beardsley; immediately west of his office was located the conference room, and next to it was Mr. [Frederick H.] Chamberlain's office. The next office was occupied by Mr. [Carl A.] Mensing, while Messers. Austin, [John H.] McMurray and [D. C.] Mix were located in the drafting room.

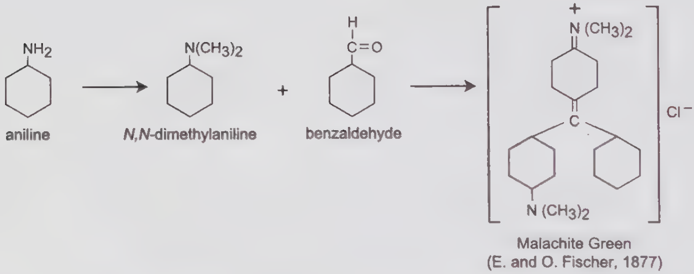


Typical steps in production of an azo dye

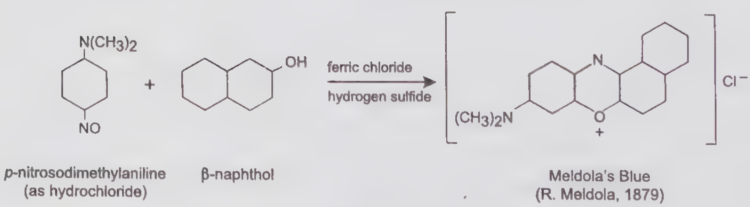
On the second floor were located the executive offices occupied by Mr. Jeffcott, Mr. [F. Miller] Fargo, and the general sales offices, while the accounting, purchasing and traffic offices were located in the large room to the west. The third floor was occupied by dormitories, kitchen and dining room.



Methylene Blue, thiazine dye



Malachite Green, triphenylmethane dye



Meldola's Blue, oxazine dye

Three important dyes discovered in the 1870s and manufactured by Calco

It is interesting to note that with the exception of A. H. Smith who passed away in 1932, all these men are with the company today [1935].[21]

After the United States entered World War I in 1917, Sidney C. Moody, engineers McMurray and Russell A. McCarty, and several others enlisted for service. F. Miller Fargo Jr. joined the Dyestuff Committee of the War Service Committee of the U.S. Chamber of Commerce. There was soon important war work to be done at Calco, whose success with the manufacture of coal-tar products came to the notice of ordnance personnel. They had failed to coerce DuPont into embarking on manufacture of the aniline derivative tetranitroaniline, or TNA, previously made at the Aetna Chemical facility, which had been destroyed by an explosion. TNA was in any case much better suited to production at the new Bound Brook intermediates factory. "The Germans were the only manufacturers of this product and, it being a high explosive, our Government was anxious to have it to act as a booster for deep sea bombs, etc."[22] There were two major advantages in the TNA process: "TNA did not require the valuable and increasingly rare toluene," used for TNT, nor the caustic soda employed in the manufacture of synthetic phenol, used for picric acid. Calco agreed to undertake the manufacture of TNA, with the assistance of the British-German patentee, Bernhard J. Flürscheim.[23]

On November 17, 1917, an agreement was drawn up between Jeffcott and the Ordnance Department for manufacture at Bound Brook of TNA at the rate of 7,500 lbs. per day. The government-funded plant, constructed on land west of Calco, was referred to as the "West Works" and consisted of six new buildings, "intended solely for explosive production." The original Calco works for intermediate and dye production was known as the "East Works." Haynes emphasized that the war plant was "a big job, a rush job, and a dangerous one. It involved a new process; the erection of 14 buildings [six at the West Works], many of special construction; a power plant and the purchase of a 140-acre farm nearby [at Millstone] where the hazardous drying operation was carried out and storage magazines located."[24]

During the construction, Flürscheim returned to England for several months, and was replaced by two men from the former Aetna factory. However, for the government contract Calco preferred to rely on its own people and Yale's Treat B. Johnson. Reminiscing on these events in 1935, McMurray wrote:

It became evident that a separate technical and operation staff would be required to carry on efficiently a work of this magnitude and the "West Works" group was organized with Mr. F. H. Chamberlain in general charge, assisted by Capt. Merritt and Messers. Mensing, Beardsley, Bengis, Mix and [C. L.] Jones ... It was during this period that our standard manufacturing building was designed and the general plant layout conceived. The plan as conceived at that time has been closely followed out in subsequent building operations.[25]

The TNA manufacturing processes were similar to those employed in production of nitrobenzene and aniline. Benzene was nitrated to dinitrobenzene, which was selectively reduced to *meta*-nitroaniline (MNA). This crystallized out from sulfuric acid as the sulfate salt, and was then nitrated to afford TNA during six hours in reactors of 2,500-gallon capacity. The product was separated from spent acid by filtration, then water washed, and again filtered, with "the finished T.N.A. crystallizing out in beautiful yellow-green rhomboids." Calco's Beardsley was closely involved in this work. Final operations, particularly drying, were carried out at what was then called the East Millstone plant, the 140 acres that had been purchased for the purpose. With 20 percent water content the product was safe to handle and transport. Wartime expansion in intermediates at the Calco East Works was confined to the installation of additional equipment for aniline manufacture and the building of a new nitrobenzene house.

For the West Works, sulfuric acid and nitric acid plants were installed, as well as a second spent-acid concentrator. The works required 40 tons of sulfuric acid every day. Water for cooling and production purposes was pumped from the Raritan River along a 1,400-foot pipeline. Extensive research was carried out into process improvements, both at Bound Brook and Yale.

The nitric acid plant consisted of six large retorts at a capacity of approximately 10 tons per day. This plant was operated until the advent of nitric acid synthetically produced from ammonia [after 1920]. The chemical staff which was organized conducted research upon the various steps of the process. Pilot Plant tools similar to those proposed for the main plant were built and the various steps in the manufacturing operations were studied in great detail. The work of our own staff was supplemented by Prof. T. B. Johnson ... who conducted a series of investigations upon the final nitration. As a result of this work it was possible to set up controls which minimized the hazards of an otherwise exceedingly dangerous operation.[26]

The strategic nature of the plant meant that it had to be protected from unwelcome observers and possible German saboteurs, who were suspected of having caused the large-scale destruction of munitions stored at Black Tom, Jersey City, in July 1916, and at Kingsland, also in New Jersey, in January 1917. "In accordance with the Ordnance Department's regulations the West Works were fenced and guarded night and day and, as the work had to be pushed to completion, this meant night and day crews and nccessitated employing all kinds of man power." At Bound Brook, at least one questionable character was well remembered. Under the "watchful eye of our Mr. S[tanley] W. Warzala" an individual "who was constantly making notes" was observed outside the fence. The suspicious fellow was reported to F. H. Chamberlain. The latter "communicated this information to several loyal members of the staff who, confident that this man was a spy, took quick action to see that he was given a proper send-off. The last that was seen of our unwelcome associate was that he was making excellent time up the railroad track, followed by a howling group of chemical workers."

Military men were much in evidence, ensuring a strong sense of unity and purpose, and of working in tandem. "The Ordnance Department's local representatives [from the Aetna plant] were Major Paul McMichael and Lieutenant Brewster, both men of high integrity ... We were ably assisted in carrying out our work at this time by Col. W[illiam] S. Weeks (U.S. Army) who acted as Judge Advocate and kept us all in line with the red tape of the Army."[27]

The experience in setting up this operation was of tremendous value in enhancing the capabilities of Bound Brook personnel, though it was of less value to the war effort. "The construction and manufacturing operations of TNA had progressed rapidly throughout the summer of 1918 and operations had been well started when the

Armistice was signed. All manufacturing operations were stopped, and the small quantity of the TNA which had come through was delivered to the Picatinny Arsenal [Dover, New Jersey]."[28]

The main outcome of the war effort at Calco and at other firms was the emergence of a strong dye-making industry in the United States, with at least 70 active companies, mainly in New Jersey, New York, Pennsylvania, and Ohio, in 1918. Four or five of these firms, Calco included, specialized in the manufacture of intermediates. For the U.S. synthetic organic chemicals industry in general it was a time of unprecedented growth, particularly in northern New Jersey, where: "It has been said that during World War I there were more than 28 chemical companies along the tracks of the [Central of] New Jersey Railroad between Jersey City and Bound Brook, a distance of 35 miles."[29] Much of the growth had been sustained by information gleaned from German patents, arrangements with English firms, and persistence and ingenuity in design and making up of novel equipment and processes. The main U.S. manufacturers of dyes were National Aniline, which in 1917 produced 106 out of the total of 180 American-made dyes, and DuPont. After them came Calco, Newport Chemical Company (Milwaukee, Wisconsin), and Ault & Wiborg Co. (Cincinnati, Ohio), each of which produced intermediates and around 12 dyes.[30] Sherwin-Williams (Cleveland, Ohio) also made dyes and dye intermediates, though not at Bound Brook. In 1918, Calco purchased two plants in Newark, one that had been hastily set up by the New York chemicals marketing agency Marden, Orth & Hastings during the war; both plants had engaged in the manufacture of the important black colorant nigrosine. The nigrosine process was taken up at Bound Brook in 1920, as part of reorganization, while: "In our outlying plants the manufacture of salicylic acid was transferred, shortly after World War I, from Walkerville to Burlington (Neidich), N.J., and the manufacture of methylene blue from Burlington to Jersey City." Calco-made dyes were sold through the Marden, Orth & Hastings Corporation.

As at other factories where coal-tar intermediates were manufactured, Calco also began the manufacture of drugs during World War I, particularly Bayer's Atophan (phenylquinoline carboxylic acid), used to treat gout and rheumatism. A Yale graduate, Louis Freedman, undertook extensive bench studies on this product before embarking on doctoral studies at Columbia. The main development work at Bound Brook, in a laboratory constructed in a former dwelling just to the north of the Central of New Jersey Railroad, was carried out by Morris S. Fine, who joined Calco in 1916 from Post Graduate Hospital, New York (he later became research director at General Foods Corporation). Production began on a small scale in Erlenmeyer flasks, but lack of space meant that the drug had to be made at Newark, again in small batches, this time in over a hundred flasks. Calco's product, called Cinchophen, was introduced in September 1917; in 1918 the firm's leading technical expert, Victor L. King, scaled up the process.[31] For a year or two, Calco was the main American manufacturer of Cinchophen; the process was transferred to Bound Brook in 1920. An ester was later produced, Neocinchophen, and both drugs were made on a relatively large scale until the mid-1930s, when side effects leading to occasional deaths, apparently 1 in 30,000, caused their demise. Another Yale student of chemistry was Henry Stoddart Johnson, who during the summers of 1918 and 1919 worked in the laboratory in building 1.

Production difficulties and holdups in the years following the war were caused not only by lack of familiarity with the new technology.

> It was during this period (February 1920) that Calco experienced one of the worst floods in the history of this valley. Several days of rain brought down the snow and ice from the upper reaches of the Raritan and Millstone Rivers. Floating ice and debris lodged at the [Fieldville] dam below Bound Brook, with the result that the Raritan River overflowed its banks and the water swept across the plant. For a number of hours there was approximately 18″ of water on the manufacturing building floors ... many weeks elapsed before we completed repairing the damage occasioned by that flood.[32]

Flood-prevention measures followed, at first diversion, by a loop to the west, of Cuckold's Brook and then, a few years later, the building of a protective dike (the main dike was constructed in 1936). Also in 1920, there was a serious explosion in the aniline shop.

These interruptions did not dampen the spirits of the Calco directors, certainly not of Jeffcott. "Rob Jeffcott was never so happy as when he had a construction gang at work and draftsmen drawing plans

Calco Chemical Company, Bound Brook, in 1915. From left to right: Building 1, office, library, and laboratory; building 2, the original beta-naphthol plant; and building 3, where nitrobenzene and aniline were produced. (*Dyes Made in America, 1915–1940* [Bound Brook: American Cyanamid Company, 1940]/Edelstein Collection.)

for a couple of additional buildings. He laid out not only a logical program to strengthen and broaden the manufacturing position, but also to multiply production facilities in an orderly fashion." However, as the facility grew in size there were occasional problems with neighbors. "A sulfuric acid plant was added and they had less trouble with the process than with a neighboring nurseryman who complained of fumes. They bought him out and acquired useful land and a nice greenhouse."[33]

Calco Chemical Company, around 1917. View looking north, showing the then largest building, no. 8 (later no. 30), where beta-naphthol, azo dyes, and dimethylaniline were manufactured. In front are, from left to right: building 11, the refrigeration plant; building 9, the boiler house; and the transformer house. Buildings 1, 2, and 3 are behind building 8. In the right distance is the Hemingway & Co. insecticide factory. Note the extent of rail sidings at this time, the barrels in which products such as beta-naphthol were distributed, the boundary fence separating the "West Works" from the "East Works," and the water tank marked "Calco Chemical Co." To the north is the Central of New Jersey Railroad, and, beyond, the Heights of Middlebrook. The three-story administration building was located to the left of the area shown. (Edeistein Library.)

These three photographs of the Calco Chemical Company were taken in July 1918 by Henry Stoddard Johnson, a Yale chemistry student who worked at the facility in the summers of 1918 and 1919. They were taken from the north, moving east to west. Johnson notes on the reverse of the first photograph, at left: "The lab where I work is seen directly beneath the water tower. The administration building [no. 40] is at the right. In the center is the Beta-Naphthol plant." On the reverse of the second, at center, he observes: "The road at the center is not the main road but a private entrance road to the plant. At the right is the administration building and at the extreme left laboratory no. 1 [in building no. 1] where I work." And on the third: "Another view of Calco from the right of the first photo, showing the newly constructed buildings for the manufacture of T.N.A. All in the picture is part of the new plant except the building at the extreme left." The three-story building shown at center, part of the government "West Works," and later Calco no. 41, was the largest manufacturing building until the early 1930s. To its right is the smokestack of the power station. (Henry S. Johnson/Bound Brook Memorial Library.)

Calco People

Right from the start, Calco was associated with talented and ambitious chemists and technical staff, some, such as chemist Robert W. Cornelison and engineer Carl Mensing (later director of engineering), brought over from Cott-A-Lap, others from acquired companies, hired on the recommendation of Johnson, or through Jeffcott's contacts. Jeffcott recruited Mensing, along with Jones, McMurray, and McCarty, from American Locomotive Works in Schenectady, New York.[34] In 1920, Colonel Weeks, who represented the interest of the U.S. Army in the supervision of the West Works, was enlisted as assistant company secretary, and in 1923 appointed secretary, a post he held for over three decades. It is not possible to trace the careers of all those involved in the early years of Calco, though a few words about some of them, and the accounts and reminiscences of others, provide useful glimpses of academic and industrial backgrounds, and of the first decade. In some cases they serve as introductions to individuals whose influences on Bound Brook were to be long lasting.

In 1918, Moses Leverock Crossley was appointed chief chemist. Crossley, born in 1884 on Saba Island, Netherlands Antilles, studied at Brown University, where he received the Ph.B. degree (1909), M.S. (1910), and Ph.D. (1911). Haynes stated that he arrived at Bound Brook "straight from a professor's chair at Wesleyan University [Middletown, Connecticut]," though he omitted to add that Crossley had acted as consultant to the Barrett Co., of New York, during 1916–18. Crossley, according to Haynes,

> was then so ignorant of plant operations that he had never seen a filter press and one of his first tasks was to separate crystals from a tarry liquid in this apparatus, which consists of a series of metal frames across which are stretched felt sheets through which the material to be filtered is pressed mechanically. He looked the contraption over and immediately adopted the commonsense solution of dissolving the tar before trying to filter it. He became famous for this practical approach and applied it successfully by synthesizing, manufacturing, and applying coal-tar dyes.[35]

During the early 1920s, Crossley undertook studies into manufacturing processes for naphthalene derivatives, and also examined color and constitution relationships for a number of their derived azo dyes.[36] Crossley, in common with other chemists and management personnel connected with the site, was prominent in the local and national chemical and dye industry communities. This did much to enhance the visibility of, and promote, Calco's interests. During 1924–26 and 1934–36, Crossley was president of the American Institute of Chemists, a body founded in 1923 that grew out of the New Jersey Chemical Society. The institute's professional training committee, appointed by Crossley, included, as secretary, Calco's Dr. Maurice L. Dolt. Crossley was a member of the American Chemical Society's Committee on Occupational Diseases in Chemical Trades. In 1936, he became director of research at Calco, and in 1941 of American Cyanamid.[37] Crossley retired in 1949, and joined Rutgers University.

Undoubtedly one of the greatest names associated with Bound Brook was Victor Louis King, who, according to Jay Leavitt, "knew the purpose and location of every pipe in the plant." An imposing figure, he was eventually appointed technical director of American Cyanamid's Calco Chemical Division. King was born in Nashville, Tennessee, in 1886. He studied at Dartmouth College, Hanover, New Hampshire, during 1903–06, after which he spent a short time at Columbia School of Mines, prior to becoming, later in 1906, smelter superintendent at the Elizabeth Copper Co. (later Vermont Copper). In 1908, he was a consulting chemist at Peter D. Austien in New York, and in the following year developed silicon carbide filaments for Professor Parker, at Columbia University. Patents were assigned to the Parker-Clark Electric Co., and later to Helion Electric Co. King began making filaments at a small plant in Newark. In common with many American graduate chemists wishing to further their careers, he then embarked on doctoral studies in Europe. King chose to work under Professor Alfred Werner at the University of Zurich.[38] His 2,000-odd crystallization experiments, carried out during 1910–11, led to the demonstration of optical isomerism in transition metal complexes, contributing greatly toward the studies that gained Werner the Nobel Prize in 1913.[39] King was awarded the Ph.D. in 1912, after which he worked for a short time with Professor Richard Willstätter, prominent specialist in plant pigments and coal-tar dyes, at the Swiss Federal Polytechnic in Zurich.[40] Late in 1912, he was offered a post as plant superintendent at Hoffman-La Roche at Grenzach, in Germany, just over the border from Basel. He believed "that the only way to do anything in chemistry in this country was by having learned the business from [Germany], and I knew that it couldn't be learned in the universities alone but must be learned in the factory." King, however, decided to postone taking up the Grenzach appointment and returned to the United States, where he worked for ten or eleven months at Parke-Davis & Co. in Detroit. There "the business of being a research chemist didn't appeal very strongly to me." After this he joined Hoffman-La Roche as a works manager at Grenzach, though he was also in charge of carbolic acid (phenol) production at Ladenberg, leaving on January 1, 1915, at the expiration of his contract.

King once more returned to the United States, where, in response to chemical shortages from Germany, he set up plants for phenol, and aniline and its derivative paraphenylenediamine, at Newark for Thomas A. Edison, Incorporated. These aromatic compounds were required for manufacture of phenol-formaldehyde resins, similar to Bakelite, suitable for phonograph records. The resin processes had been extensively researched at Edison's West Orange laboratory, New Jersey, by consulting chemist Jonas W. Aylesworth, who around 1910 discovered an improved process using, as catalyst, first hexamethylenetetramine, and then paraphenylenediamine. Aylesworth's patents were the basis of phenolic-resin processes employed by the Condensite Company of America, founded in 1910, and in which Edison had a controlling interest. Edison's involvement in the large-scale manufacture of coal-tar derivatives began, at the outbreak of war, with a new synthetic source of phenol. Phenol was no longer imported, mainly from England, nor available in adequate amounts as a by-product from U.S. coke manufacturers, in part because supplies were required for manufacture of the trinitro derivative, the explosive picric acid. Until 1914, Edison received phenol from Condensite, which was dependent upon the Benzol Products Company and coke manufacturers. Benzene was now to become the starting point for synthetic phenol. Edison's laboratory staff developed a process for industrial manufacture of phenol based on sulfonation of benzene, followed by caustic fusion. He manufactured the chloride salt of paraphenylenediamine by reducing *para*-nitroaniline with iron and hydrochloric acid. The free diamine was liberated by addition of sodium hydroxide. Apart from its use as a catalyst, paraphenylenediamine was also employed on a large-scale as a black colorant for fur; for this purpose Edison's product was exported to Europe and Japan.

King's first assignment for Edison was to convert benzene, successively, into nitrobenzene, aniline, and, finally, paraphenylenediamine. He "entered into the spirit of this job ... and built an aniline plant in 24 working days which operated exactly as expected, and although the plant was extremely simple, its efficiency was very good. We used the tank cars in which the benzene and mixed acids came to us as storage tanks and built our plant alongside the railroad for that purpose. We dumped our sludge and ran our mixed acid on top of it to neutralize it before running it into the sewers and succeeded in making a very satisfactory aniline oil over a considerable period of time. The aniline oil we worked up into acetanilide and paraphenylenediamine, and for a time we made a little paranitraniline for sale."[41]

Edison installed plant for recovery of benzene and other coal-tar hydrocarbons at the Cambria Steel Company, Johnstown, Pennsylvania, and the Woodward Iron Company, Woodward, Alabama. King had to sort out teething problems at Cambria's "benzene-toluene-xylene plant for the recovery of these materials from coke oven gas," soon after his new aniline plant at Newark was ready. Edison's "people down there were unable to produce benzene, and with characteristic brusqueness he ordered me to put on my hat and go to Johnstown and stay there until benzene could be shipped, which I did."[42]

Edison ran down his chemical manufacturing operations during 1917, partly on the advice of King, who in May of that year joined American Synthetic Dyes (co-owned with Butterworth-Judson Company by Butterworth-Judson Corporation, of New York City) at Newark Transfer and erected plant for synthetic phenol and picric acid.[43] To ensure that potential saboteurs did not gain access to this important war production site, King employed hundreds of black Americans brought in from the south: "I endeavoured to engage nothing but negroes for workmen on the assuption that by hiring only negroes I would effectually prevent the entrance into the organization of any enemy aliens." Following a dispute with the vice president of American Synthetic Dyes, King resigned and found gainful employment in the manufacture of picric acid and other chemicals for various firms, partly acting as a consultant attached to Bernard Baruch's War Industries Board.

The foregoing information derives mainly from a lengthy career profile that King prepared in December 1926, apparently in support of an application for advancement at Calco, which had just emerged from a difficult, almost crippling, trading period. This and King's other writings, though often repetitive in style and content, are some of the most important historical firsthand accounts on Calco that survive. They show how he developed a broad range of contacts, laid out his philosophy and developed his strategies. In this case, the richly detailed document not only demonstrates the way in which King managed his career, but includes details of his work in environmental monitoring in the Newark Bay area mainly during 1917–18 for the Hudson County and New York City law departments. King was engaged by the

> Prosecutor of Hudson County and also by the Corporation Counsel of New York to make inspections of a number of factories in the Newark Bay section and reports thereof and recommendations thereupon with reference to the fume nuisance and the emission of obnoxious and unpleasant odors. This intermittent work, which went on for some time, gave me an opportunity of visiting in practically an inquisitorial capacity, several chemical and fertilizer factories in the Newark Bay district. I think that as a result of my reports and testimony some very proper injunctions were granted. The Corporation Counsel of New York City engaged me for a very similar purpose with reference to the chemical factories on the Hudson River just opposite Riverside Drive, all of which I inspected and examined repeatedly, and particularly the Corn Products Refining Company, the General Chemical Company and the Kalbfleisch Corporation, and I made reports and gave testimony before the State Commissioner of Health, New York City, repeatedly on this subject.[44]

In part 2 of this story we shall see how King led efforts to reduce pollution of the Raritan River and atmospheric releases from Bound Brook, and also how New Jersey Department of Health inspectors visited Calco in what the company, including King, must have considered to have been an "inquisitorial capacity."

King's experiences with coal-tar intermediates for Edison and others gave him the background knowledge that in 1918 was vital to the strategic industry of dye manufacture:

I made arrangements to enlist in the Army but I was asked by Mr. Chas. MacDowell of the Armour Company to take the [Artificial] Dyes & Intermediates Section of the War Industries Board, which I did. This working for a dollar a year was a very real sacrifice for me for I wasn't President of any company that could continue to pay my salary. However, at Mr. MacDowell's insistence, I took charge of the section of dyes and intermediates in [September 1918, replacing Jacob F. Schoellkopf Jr.] and remained until the first of January 1919. The experience with the War Industries Board was extremely interesting and I hope broadening. I don't know how much I accomplished for the Government but at least I had the pleasure of associating with those who were doing things and that was a very pleasant experience. I got a very clear insight as a result of this work of how some things can be done on a very large scale.[45]

The Edison and government service certainly provided King with access to all aspects of the manufacture of coal-tar aromatic chemicals—particularly experience of overseeing design, construction, and operation of typical equipment—in addition to contact with leading firms, including Calco. It was probably late in 1918 that King first met Robert Jeffcott. Early in the following year "and after several meetings with him and Mr. Berry I was engaged to work for the Calco Chemical Company ... it was decided to have me take charge of the [former Mardin, Orth & Hastings] plant in Newark, which I did and ran that plant until about the first of March 1920. This was a very poorly war-built plant and I urged its sale which was soon made."[46]

Despite the natural emphasis on his own achievements and energies, the self-promoting account drawn up by King is the most valuable record of the early postwar technical developments at Calco. At Newark, he "developed the manufacture of the nigrosines, introducing some novel innovations into the process that had decided price reducing effects. As a result, I was able to design the present nigrosine plant at Bound Brook." Also at Newark, King introduced the manufacture of Tolysin (*para*-methyl-phenylcinchoninic acid ethyl ester), a preparation of the antipyretic Neocinchophen, a pharmaceutical which has been very profitable ever since—in fact, one of the most profitable of our products. In this plant also I developed the manufacture of dinitrobenzene and today [1926] Calco is perhaps the leading manufacturer of this product.

After the sale of the Newark plant, I came to Bound Brook, about the first of March 1920, and was impressed by Mr. Jeffcott with the necessity of, as rapidly as possible, making 1,800,000 lbs. of aniline and 1,000,000 lbs. of beta-naphthol per month. I was placed in charge of the nitrobenzene-aniline plant and in about 100 days succeeded in so altering the process and equipment in the aniline plant as to get the production of aniline oil from 750,000 lbs. up to 1,500,000 lbs. and still rising, without at the same time lowering the yield or increasing the cost. As a matter of fact, during this period, the yield was increased materially and the cost was actually lowered.

King claimed a similar level of success with production of beta-naphthol.

I was then transferred to the beta-naphthol plant which plant I ran until the first of January 1921. In 90 days, I raised the production from about half a million pounds to over a million pounds ... the yields show a slight improvement, I think, [and] as a result of 6 month's concentrated and uninterrupted efforts on beta-naphthol, we obtained, for the first time, an exact knowledge of what the process consisted and, as a result of my work, I prepared exact operating instructions for both aniline and beta-naphthol, which have since been the basis for operation of these processes.

These and other cost-effective innovations, and the resulting profits, enabled King to claim for himself a role in Calco's success at raising much-needed capital for expansion through a public bond issue offering. This was certainly an achievement, since Wall Street bankers in the early and mid-1920s were generally wary of investing in the somewhat precarious chemical industry.

The rapid raising of production of aniline oil and of beta-naphthol contributed to the very rapid rise in gross sales which certainly very largely aided in the placing of the $2,000,000 bond issue.

After the above work was completed, [and] the nigrosine plant which I had designed had been built [and] was ready ... I put it into operation, trained its crew and turned it over to Department C [nigrosines] in the course of 60 days.[47]

King was also responsible for improvements in the production processes for finished dyes, and by the mid-1920s had personally managed each of the manufacturing departments. His maverick background—academic research, work in the Swiss–German chemical industry, entrepreneur, environmental inspector, technical assistance to Edison, government service in wartime, and process improvements at Calco—provided the credentials that enabled King to project himself as a manager of technology.

In the fall of 1920, the charge of the methylene blue plant in Jersey City was turned over to me by the General Manager [probably Jeffcott] to put in shape. I had already sent one of the men there who had been working with me in Newark and although at long distance, by having the two men in the plant, the Superintendent and the chemist, report to me twice a week and by programming the work which they were to do, and by interpreting the work which they reported, I succeeded in the three months of October, November and December, in very radically revolutionizing the whole process of the manufacture of methylene blue, chemically and mechanically, with the result that I was able to design the process and the plant, which has cut the labor charges in more than half, due to the mechanical improvements, and simpler schemes of operation.

During the same period I was directed by the General Manager, in a Production Control Meeting, to work out a safe process for the manufacture of chrome brown powder, a product which the Sales Department had been vigorously calling for. I succeeded in this respect and we have been making this product satisfactorily ever since. I think its timely production contributed very largely to our not losing out in the retention of the chrome brown business.

The Calco Chemical Company since the above was written has employed me in various capacities in addition to that of manufacturing Technical Director—Chairman of the Works Committee, manager of various Departments, etc. At one time or another I have managed each of their manufacturing departments. I believe that the work in organization which I have been able to do for them has been much more important than any of the other specific items mentioned above.

As indicated by King, Calco created separate operating departments, originally called divisions, the largest of which was for intermediates production, originally known as Division A (mainly betanaphthol).

King also emphasized the advantages to Calco of his extensive European business connections, important sources of new processes and products. "I have spent a good deal of time in Europe for them [Calco] and have visited every European country from Spain to Hungary and Sweden and of course broadened my European acquaintances. I have been in Europe for this company once or twice every year since 1922 to date. The European relationships that I have developed have been in most cases quite satisfactory and profitable." King continued to develop these contacts at Bound Brook, where he was to remain until retirement in 1951, after which he acted as consultant to American Cyanamid.

Worthy of mention, even though he worked at Calco for less than a year, is R(andolph) Norris Shreve, promoter of unit processes as a concept in chemical engineering, and noted textbook author. His connection with Calco and later American Cyanamid as a consultant was to last over three decades. Born in 1885, Shreve started his industrial career at Mallinckrodt Chemical Works Co. Later he studied chemistry at Harvard (1904–07), after which he returned to Mallinckrodt. In 1911 he was with Lamar Chemical Works, Newark, and three years later he started Shreve Chemical Company. Shreve Chemical became associated with the Newark plant of Marden, Orth & Hastings that was acquired by Calco in 1918. Shreve remained with Calco until 1919, then becoming an independent consultant.[48] He joined Purdue University in 1930 and started a teaching program in chemical engineering, called organic chemical technology. In 1935 he developed the concept that industrial chemistry was based on unit processes. His work on alkylation was supported by American Cyanamid from 1946 to 1952. Shreve retired in 1955.[49]

Another notable individual associated briefly with Bound Brook, probably as a result of King's European contacts, was the Swiss-born chemist Dr. (Jean) Felix Piccard, twin brother of Auguste Piccard. Felix studied technical chemistry, particularly coal-tar dyes, at the Swiss Federal Polytechnic, Zurich, where in 1909 he received his doctorate, supervised by Richard Willstätter. During 1910–14, Felix

Piccard was Privatdozent and assistant of Adolf von Baeyer at Munich, after which he was appointed professor of chemistry at the University of Lausanne. He left for the United States soon after World War I. Piccard's personal papers, many undated, show that he undertook extensive research into aromatic intermediates and dyestuffs, which is no doubt why from 1924 to 1926 he was engaged as a consultant to Calco. During that time he completed work on studies into color and constitution—a topic of great interest to Crossley and other Calco scientists—that he had commenced in 1913.[50] Piccard joined MIT as research instructor in 1926. Following a short research career in chemistry he became increasingly engaged in the Piccard family involvement with stratospheric exploration. During 1931–32, Auguste Piccard, then a professor of physics at Brussels, ascended around 16 kilometers (52,000 feet) by balloon at Augsberg, Germany. In 1933, the Piccard brothers designed the gondola *Century of Progess* built by Dow Chemical Company for the Chicago World's Fair. Later, Felix refurbished the *Century of Progress*, and in 1934, with his wife, Jeannette, ascended 18 kilometers (57,559 feet) from Dearborn, Michigan, to study cosmic rays.[51]

Because of their brief associations with Bound Brook, both R. Norris Shreve and Felix Piccard might seem somewhat peripheral to this story. However, they do bear larger meanings in that they engaged in activities that came to define some of the most conspicuous achievements of Calco. These were, respectively, the codification of a system of chemical engineering that focused mainly on the production of aromatic intermediates, and increasingly science-based ways for understanding color at the molecular level, designing colorants, and measuring color. These topics greatly interested Moses Crossley, while Victor King certainly appreciated rational approaches to synthetic pathways for coal-tar intermediates. They were the core themes of the 20th-century synthetic dye industry.

Chapter 2

Integration, Expansion, and Takeover

"Integration means where there is a great interdependence of processes of manufacture and where large quantities of various raw materials are converted by many successive steps into smaller and smaller amounts of greater and greater numbers of intermediate products to produce a whole galaxy of final products of most diverse character."—Victor L. King, "Chemical Progress at Home and Abroad," lecture manuscript dated May 20, 1954. King Papers, MS 429, Dartmouth College Library.

In October 1917, not long after the United States entered World War I, Congress passed the Trading With The Enemy Act, and the Office of Alien Property was established, with Judge Alexander Mitchell Palmer as its first custodian, and lawyer Francis Patrick Garvan in charge of operations. The act enabled the Federal Trade Commission to issue licenses for the use of German patents, particularly dyestuffs and pharmaceutical products. For the latter, which included Bayer's aspirin, the commission set up an advisory commission through the National Research Council's Subcommittee on Synthetic Drugs. This was a novel situation in the United States, since prior to the war the medical profession had lobbied strenuously against the filing of patents by American firms and inventors for pharmaceutical products. By early 1918, Calco was one of four companies granted licenses for the anesthetic Novocain, originally introduced by Hoechst in 1906, in addition to Atophan (Calco's Cinchophen).[1]

After the war, through the Chemical Foundation, Inc., founded early in 1919, alien property in the form of patents was made available to manufacturers of dyes in the United States. Garvan was appointed president of the Chemical Foundation, where he remained at the helm until his death in November 1939. The Chemical Foundation, through its purchase of patents from the Office of the Alien Property Custodian, became the instrument through which American firms, including Calco, availed themselves of previously inaccessible German processes. This appropriation of intellectual property rights was part of the war booty that America had sequestered after Congress suspended the privilege of monopoly accorded to German patents. The growth of the coal-tar chemical industries, however, needed more than free access to German patents. It required organization of manufacturers to ensure adequate profits and to combat the future threat of German imports. Robert Jeffcott was active in the founding of the American Dyes Institute, a body consisting of 46 manufacturers in 16 states that lobbied to become an "open price society" (that to some observers suggested price-fixing). In this objective, the institute failed, though it enjoyed a brief period of prominence when the Dyestuff Manufacturers' Association of America (in which Jeffcott was also involved) collapsed in January 1919.[2] Despite the setbacks, including arrival of German dyes (as part of the reparations agreements drawn up by President Woodrow Wilson, his advisers, and heads of the victorious European states at the Treaty of Versailles), this was an important phase in the establishment of effective trade and professional bodies that would serve the dye industry. To support the industry the American Chemical Society created a Division of Dye Chemistry in 1919 (merged with the Division of Organic Chemistry in 1935). From the standpoint of investors, however, the complex technology of dyes was poorly understood, and did not seem to offer the same return as other manufactures.

The Roaring Twenties

Interest in the production of colorants was stimulated by the fact that between the two world wars the use of color in American life became à la mode. In the 1920s, the impact was significant and highly visible far beyond the world of textiles and high fashion. "Coal-tar has brought more colour into our dull lives, not only through our clothing but also through our food ... The red dyes go largely into frankfurters and the yellow into butter and rival spreads, while all the colours of the rainbow are in demand for cake and candy icings and ice cream." The use of dyes in non-alcoholic beverages was even claimed to promote law and order in the era of Prohibition (1920–33) since it assisted in "gradually weaning the American people away from hard liquor."[3] The Color Laboratory at the Department of Agriculture's Bureau of Chemistry, opened in 1916, had a major impact on the use of dyes as food colorants, for which about 500,000 lbs. were added annually to foodstuffs and beverages.[4] This application of dyes was brought under strict control in later years, and Calco was one of eight American firms whose products were authorized for use in foodstuffs by the Food and Drug Administration.

In the United States during 1920, around ninety factories produced 88 million pounds of dyes, which was 15 times the output in 1914, and far greater than in 1919. The value of U.S.-made dyes was $95 million, of which almost one third was exported "which is a big advance over 1914 when we exported only $400,000 worth."[5] Output fluctuated, however, as did perceptions of the industry.

> The production of coal-tar compounds is an important industry ... But it is not a big business. It is one of the minor chemical industries as measured by financial income or avoirdupois output. It does not compare in these respects with such chemical industries as steel-making, glass-making, sugar-making, or cement-making. The coal-tar dyes manufactured in the United States in 1921 were valued at $32,400,000, but the chewing gum manufactured was worth–or was sold for–much more ($51,240,000 in 1919).[6]

Though the Calco Chemical Company–with, in 1920, around 140 employees, including at least 35 women–manufactured some 50 products, including azo and triphenylmethane dyes, the main emphasis remained on production of intermediates. Calco aspired to become the principal supplier of coal-tar intermediates to manufacturers of synthetic dyestuffs. This however was not to be: "1921 was an off year all round." Dye exports were valued at only $6,270,000. American manufacturers still could not meet all the home demand for every type of dye, "so in 1921 we imported about 4,000,000 pounds of dyes valued at $5,000,000, about nine tenths of which came from Germany and Switzerland."[7] Ivan Gubelmann of DuPont later observed that "the investing public and the bankers had almost completely lost faith in our industry ... The industry had clearly overexpanded, had been overcapitalized, and had maladjusted manufacturing facilities."[8]

In this situation, Calco's plans floundered. The future began to appear bleak, partly because Calco had not developed its own extensive dye-making capacity. Calco "competed in a half-hearted manner against other manufacturers, from whom it obtained dyes in return for Calco-manufactured intermediates, the dyes being returned to Calco on a preferential basis."[9]

Haynes summarized the situation thus:

Dyestuffs had never been emphasized [at Calco] and the year taken out of their own development work by the TNA job had checkmated diversification in colors. Jeffcott's idea was to supply other dye makers with intermediates. If research and production could be concentrated in a single company, the whole American dye industry could be supplied these basic chemicals of higher quality and better standardization and at lower prices. This sensible program failed for two reasons. Casualties among the smaller dye companies were heavier than anticipated. The strong surviving companies felt, quite logically, that they should not be dependent upon an outside source for these essential materials. Willynilly, Calco was forced into dyes. The early 1920s were dark and dismal years. Recalling them at an employees' banquet, Sidney Moody said, "Those were the days when the Sheriff of Somerset County pitched his tent across the railway tracks from Calco, waiting to take over the company."

Working capital was in dire need. The intermediate business had not materialized. New products had to be developed by costly research and heavy new plant investment. Twice [once in 1922] the whole executive staff took a voluntary across-the-board cut in salary; a tribute to Jeffcott's leadership and their own faith and loyalty. That was the low point.[10]

Things were no better at the rival DuPont, which also suffered considerable, though perhaps less threatening, losses.[11]

The market morass did not undermine the confidence of those who believed in the future of an American dye industry. However, there was a general overproduction of dyes during 1922–23, accompanied by a sharp fall in prices, "toluol [toluene] from $1.50 to 25c, phenol from 45c to 11c."[12] The average price of dye intermediates fell from a peak of just under $1.20 per pound in June 1922 to 50 cents in 1924, and continued to fall, as did production and sale of dyes.[13] The dyestuff industry had been helped by extension of a 1916 tariff on German dyes, through passage of the temporary Dye and Chemical Control Act in 1921. This was replaced in 1922 by the Fordney–McCumber Tariff Act that provided considerable protection to chemical manufacturers.[14] Reparations dyes were subject to tariff laws, that from this time also restricted the importation of other German dyes for sale.[15] While German-made dyes were favored by users, the reparations products were not necessarily those that they wanted, with the result that from November 1922 the United States no longer made claim to its shares of reparations dyes.[16]

In 1923, Calvin Coolidge became president of the United States, replacing Warren G. Harding, who had died after returning from a visit to the newly completed Alaska Railroad. From the dye industry's perspective, a significant event in the following January was the defeat of the government's lawsuit against the Chemical Foundation. This case included charges that industry and certain government officials had acted improperly in the setting up and operation of the foundation. A central issue was the sufficiency of German patent recipes. Calco's Crossley, one of the witnesses for the Chemical Foundation, the defendant, testified that Freedman, a witness for the plaintiff who worked on Cinchophen at Bound Brook in 1917, had, in undertaking experiments for the court, demonstrated the inadequacy of the original patent recipe. The outcome of the case, *USA v. The Chemical Foundation, Inc.*, placed German manufacturers at a disadvantage, insofar as it denied them return of patents, which in many cases were now shown to be incomplete, and payments of royalties. By upholding the legality of the Chemical Foundation, the court gave a further boost to American manufacturers.[17] This brought capital back into the dye industry, which at Calco enabled expansion financed by the bond issue mentioned in King's career profile.

While Calco had failed in its original objective of becoming the leading manufacturer of intermediates, the still difficult trading situation did provide an opportunity for the firm to acquire a number of struggling producers of synthetic dyes and coal-tar intermediates. During 1924–27, in the wake of the court decision in favor of the Chemical Foundation, and as part of a renewed effort to gain rapid access to dye technologies and markets as well as to suppress competition in intermediates, Calco, with branch offices in New York, Boston, Philadelphia, and Chicago, purchased four more companies: in August 1924, Kerin Manufacturing Company, Marietta, Ohio, manufacturer of auramine, a diphenylmethane colorant; in July 1926, Granton Chemical Company, Granton, New Jersey, producer of the intermediates nitrobenzene, dinitrobenzene (DNB), aniline, dinitrotoluene (DNT), and dimethylaniline (DMA); in October 1926, Essex Aniline Works, Boston, producer of stilbenes and chrysophines; and in July 1927, Williamsburgh Chemical Company, Brooklyn, which made malachite green and methylene blue.[18]

The extensive TNA undertaking at Bound Brook, the West Works, had been purchased from the government by 1921. Funding for the purchase may have come from over a million dollars owed by the government for the war-related work. The West Works provided additional substantial buildings where newly acquired technologies for intermediates and dyes could be transferred. It was not only buildings and additional land that were purchased from the military authorities. There was also a consignment of the surplus war gas phosgene (carbonyl chloride) bought for dye manufacture, but which escaped into the atmosphere. The whole facility was immediately evacuated.

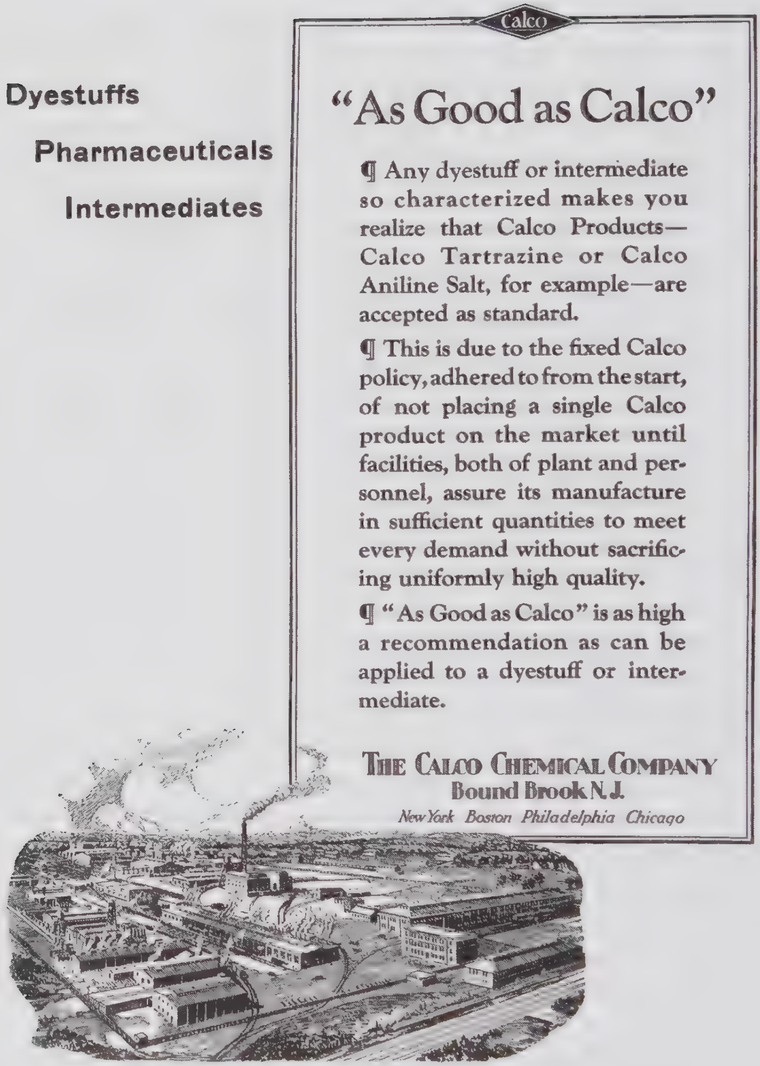
In 1924 many intermediates for dyes made in America were still imported mainly from Germany.[19] Around this time, a Standards Laboratory was set up at Bound Brook to develop analytical methods for monitoring individual reactions and sampling and testing procedures. Trade advertisements included a sketch of the much-enlarged facility. They claimed that "As Good as Calco" was the standard whereby the qualities of rival products were measured against those of Bound Brook, which included acid, direct, basic, and chrome dyestuffs, intermediates, pharmaceuticals, sulfuric acid, including oleum, nitric acid, and mixed acids for nitration.[20] This had been achieved by technical people working under the supervision of Victor King, including engineers C. L. Jones, Russell McCarty, John McMurray, and Carl Mensing—all trained in locomotive construction—and a small group of chemists directed by Moses Crossley. Later, land north of the Central of New Jersey Railroad, referred to as the Hill Property, was also taken over by Calco.

Despite progress in developing science-based manufacture, some lessons had been learned the hard way. In 1921, there was a fire in the sulfanilic acid plant, in the shed between buildings 1 and 2. The shed was not equipped with sprinklers, and the plant, including baker's oven and corn grinder, was destroyed. Early in 1926 the shed again became engulfed in fire, but this time "the entire building and contents were destroyed, much to the satisfaction of Mr. A. H. Smith, who had long feared it would lead to a more serious fire. This fire gave an excellent demonstration of the value of sprinkler protection, and the wisdom in having important manufacturing units equipped with sprinklers."[21] A formal Calco fire brigade was organized in 1925, made up of 15 to 20 volunteers, but with no fire engine.

According to the 1926 U.S. Tariff Commission report, domestic production of synthetic dyes in 1923 was 93,667,524 lbs., the output of 88 firms. In 1924, this fell to 68,679,000 lbs., made by 78 firms. The reduced output was due mainly to decreased activity in the textile industry, as well as stocks carried over from 1923, lower exports, and a 15 percent reduction in the duty on imported dyestuffs and intermediates, as of September 22, 1924. Despite slowdowns in the textile mills of New England and the south during the following spring, there was a 25 percent increase in 1925, to around 86 million lbs., arising from greater domestic textile production later in the year, particularly sudden demand for the new synthetic rayons and silk, and exports, including of indigo and sulfur blacks. The tariff report drew attention to the fact that 1925 was distinguished by a tremendous increase in American-made anthraquinone vat dyes, in excess of 2,500,000 lbs., compared with just 1,821,319 lbs. in 1924.

Though uncertainty gave way to optimism in the dye industry, it was still in the start-up phase, with all the attendant difficulties, including falling prices due to "severe competition." As Gubelmann recalled:

Until 1926 many of the dyestuff-producing plants operated either at a loss or with very little profit. It was a period of tearing down, of building up again, and of spending large sums on research. Yields, operating technic, and chemical apparatus were improved step by step, which resulted in great economies, as indicated by the continued drop of prices for intermediates and finished products. New products were added in great numbers, among them many new fast-to-light direct azo colors and the vat colors of the thio indigo group. We were moving gradually closer to the ideal of establishing a self-contained



"As Good as Calco." Calco Chemical Company advertisement. (*Chemicals: A Consolidation of Chemical, Color & Oil Record; Chemical Age and The Chemical Engineer; Color Trade Journal and Textile Chemist* (Dyestuffs Edition) 23 [May 25, 1925]: 16.) Another Calco product "accepted as standard" was refrigerant grade sulfur dioxide (less than 5 parts per million of water) based on a process developed by Alling Beardsley.

American dyestuff industry; this period of 1921–26 was the most constructive in its history.[22]

Thioindigo vat colorants, based on a 1905 discovery of Paul Friedländer, at Vienna, and introduced by Kalle & Co., of Biebrich, Germany, were later to become important Calco products.

Despite the proliferation of names for similar or identical products, including of vat dyes, consumers were assisted by moves toward color standardization, particularly through the introduction of the Standard Hosiery Color Card of America, and the efforts of the Textile Color Card Association. The journal *Chemicals* declared that the spring 1927 color card of the latter body included "All the Colors of the Rainbow—and Some a Rainbow Never Included—Put Out for Milady's Wear," noting that the "modern girl with her fondness for masculine effects in the day time nevertheless likes to be as enchanting as Jenny Lind in the evening," with correct fashion colors to match.[23]

Research had been carried out at Calco right from the start, though in a somewhat inchoate manner. The creation of a Research Department in 1927 was the single most important innovation necessary to ensure the smooth integration of additional products and processes. With this, Calco became one of the first American chemical firms to establish dedicated research and development facilities.[24] Among the new assistants engaged to work in the research laboratories was Harold J. Rodenberger, who rose through the ranks to become, in 1956, manager of the Research and Development Department's Analytical Section, and, from 1960 until his death in 1967, the department's business manager.

Also in 1927, DuPont constructed at its Wilmington Experimental Station what was dubbed "Purity Hall," home of its fundamental research program.[25] DuPont also formalized its arrangements with consultants.[26] As at Bound Brook, this was the outcome of the move into the relative complexity of aromatic organic chemistry, initiated by dyestuffs and intermediates. These new facilities were among the thousand or so industrial and consulting research laboratories and organizations in the United States that existed in 1927, compared with about 300 in 1920.[27] At Calco, distribution and storage of standardized chemists' research notebooks began at this time, as did a system of reporting results and drawing up of current research, through investigation reports (I.R.s), that remained in force until the last day of 1954.[28]

Any inventions with commercial potential made by Calco researchers were the sole property of the company, as was the case elsewhere, and were written up as patent applications. Apart from the lien on proprietary knowledge and patentable information, the management encouraged, after approval, submission of research papers to technical and scientific journals. This was a matter of prestige that enhanced confidence in the quality of the company's products. In the long term the Calco (and later American Cyanamid) publication policy was far more liberal than was the case at DuPont, enabling Bound Brook to attract its own share of outstanding scientists.[29]

Notwithstanding this vigorous move into science-based industry, and an aggressive acquisition policy based on buying out firms that offered access to new markets or that were rivals—as well as a record level of U.S. dye production in 1928, totaling 96,625,000 lbs.—Robert Jeffcott had overextended his business.[30] The company was piling up debt, and by early 1929 was plunged into a cash crisis. Further expansion, perhaps even survival, required a cash-rich partner. This is where American Cyanamid entered the picture. It was none too soon. The difficult situation that Jeffcott had created for himself now, ironically, would save him from a calamity.

Cyanamid Takes Over

American Cyanamid was just eight years older than Calco, and had pioneered in America the use of electrochemistry for production of calcium cyanamide, the nitrogen-containing fertilizer. Cyanamid's founder was Cornell-educated civil engineer Frank Sherman Washburn, who had acquired rights to the German Frank–Caro process in 1907. Taking advantage of cheap electrical power available from the Ontario Power Company at Niagara Falls, and an abundance of limestone nearby, he established, in 1907, the American Cyanamid Company, with backing from James Duke. The plant was in Canada; the headquarters were in New York City.

Washburn produced his first batch of cyanamide in August 1909, and full-scale manufacture began in 1912. American Cyanamid expanded considerably during World War I as a result of government promotion of nitrogen-fixation processes. These were used to make nitric acid required in the synthesis of aromatic nitro compounds, not only the dye intermediates, but also explosives such as TNT and picric acid. It was the increased demand for these compounds that caused the secretary of war, Newton W. Baker, to send Charles Lathrop Parsons, secretary of the American Chemical Society, to Europe as a member of the Nitrate Commission to investigate nitrogen fixation. Parsons suggested that the American Chemical Society and Bureau of Mines conduct a census of chemists and metallurgists for recruitment into wartime service, including in the U.S. Chemical Warfare Service and War Industries Board, to boost industrial production of aromatic intermediates for explosives, dyes, and other products. This was where Victor King had made his greatest contribution until the end of 1918.

On Washburn's death in October 1922, William Brown Bell, a lawyer and Quaker who represented the Duke interests, was placed in control of American Cyanamid.[31] During the second half of the decade, Bell embarked on diversification away from the firm's specialties, calcium cyanamide, synthetic ammonia, and Florida phosphates, particularly as sales of these products began to suffer from the international collapse in agricultural prices. Also the Haber–Bosch high-pressure process for fixation of atmospheric nitrogen had become a serious competitor. Fortunately for Bell, "the booming Twenties were at their height and no longer were chemical enterprises regarded with suspicion in financial circles. In fact, they had become pets of forward-looking investors. Taking advantage of Wall Street's optimistic appraisal of Cyanamid stock, Bell began rapid diversification by exchanging Cyanamid common stock for the assets and securities of other companies."[32] Through Bell's efforts, American Cyanamid was almost singularly fortunate among chemical manufacturers in receiving generous backing from commercial banks, notably Chase National Bank, and Guaranty Trust Company, in New York, and National Trust Company, Ltd, and Canadian Bank of Commerce, in Toronto. Apart from DuPont, other chemical firms had to rely on retained profits to finance growth and diversification.

Of most relevance here was the acquisition, in February 1929, of the Calco Chemical Company, whereby American Cyanamid acquired the assets and assumed the liabilities for a consideration of 127,120 American Cyanamid common, or B, shares (American Cyanamid issued 200,000 B shares to finance the acquisition).[33] Robert Jeffcott, president of Calco, was appointed a director of American Cyanamid, of which Calco Chemical Company, Inc., was now a fully owned subsidiary. Other American Cyanamid acquisitions in the dye-making business during 1929 were: Crown Chemical Corporation, Keyport, New Jersey, mainly aniline intermediates (May); Textile Chemical Co., Providence, Rhode Island, naphthol yellow (fast light yellow), and azo yellow; the lake dyestuffs of May Chemical Works, Newark (August); and the old-established Beaver Chemical Corporation, Damascus, Virginia, "manufacturer of sulphur colors and alizarines."[34] The "Calco Chemical Co., Inc., Division of American Cyanamid Co." became the operational center for what was effectively the dyestuff division of American Cyanamid, and in most cases intermediate and dye manufacture was transferred to Bound Brook.

On July 16, 1929, American Cyanamid & Chemical Corporation was established as a producer of acids and other heavy chemicals. It included the American Cyanamid Warners facility at Linden, New Jersey, and soon after Kalbfleisch Corporation, producer of acids and mineral salts. In August 1929, the Selden Company of Pittsburgh was purchased. Selden was successor to Walker Chemical Co., that owned the Gibbs–Conover patent for conversion of naphthalene into phthalic anhydride and was the sole U.S. manufacturer of this important product, first made in 1918, and employed in vat dye manufacture.[35] Also purchased in 1929 was the Nitrogen Products Corporation.

That fateful year of 1929, however, marked the end of "Coolidge prosperity" and the booming economy of the 1920s. In October 1929, almost eight months after Herbert Hoover was inaugurated president of the United States, the bubble burst, and Wall Street went into free fall. Unemployment soon reached almost 14 million. The mass-production society that had fostered mass consumption through higher wages than in Europe was without consumers. This did, however, provide opportunities for men with vision and capital. Bell's takeover of the struggling Calco not only enabled Jeffcott's operation to ride out the storm but was followed with a strategy based on absorbing smaller firms in the dye business, often at depressed prices.

A great help to Calco employees was the introduction, from December 1, 1929, of a company-sponsored insurance scheme under contract with Equitable Life Insurance Co.[36]

American Cyanamid aggressively continued Calco's policy of taking over "some makers of dyestuffs which did not manufacture intermediates and in this manner secured a captive market for its considerable production of organic chemicals."[37] In March 1930, Passaic Color Corporation of Passaic, New Jersey, and Garfield Aniline Works of Garfield, New Jersey, were purchased, and brought to Calco acid, chrome, and vat colors. One month later, Trico Chemical Company, of Buffalo, New York, that offered a range of sulfur colors, was acquired. Encouragement came from the Smoot–Hawley Tariff Act of 1930 that placed higher tariffs on dye imports by calculating the tariff rate from the U.S. selling price. By then the Bound Brook undertaking had become a "gigantic creature of steel and concrete—spreading over 400 acres on 'the banks of the Raritan' ... And what a huge—healthy—and useful creature it is! Spitting flames from its furnaces and puffing smoke and steam from its stacks ... an army of almost 1,000 is needed to feed it ... To the army of workers it yields a comfortable livelihood and a contented existence."

William Bell's buying operations, however, were not without their non-technical problems, since, as Jay Leavitt points out, some sellers started up in business again, and in time were taken over by American Cyanamid in order to cut out the competition.

The Vat and Other Dyes, Diversification, and Medical and Rubber Products

A major addition to the range of colorants at Bound Brook had come from the decision in 1930 to enter into the manufacture of anthraquinone vat dyes, based in the new Department G. This was assisted by the acquisition of firms already in this line of business—Beaver, Passaic, and Garfield—and also through the purchase of Wetterwald & Pfister Chemical Co. and Wettersol Dyestuff Corporation, both located at the same address in New York, and Dye Products & Chemical Co., also of New York.[38] Anthraquinone was made at Bound Brook from phthalic anhydride, supplied by Cyanamid's Selden plant at Bridgeville, Pennsylvania.

Also purchased by American Cyanamid in 1930 was the 1886-established Heller & Merz Co. of Newark, which supplied a wide range of products to the paper trade. The incorporation of the Heller & Merz dyes and pigments into Calco marked the latter's entry into the important sector of paper coloration and printing, particularly with so-called dry colors, or pigments. Under vice president August Merz, Heller & Merz had become the largest and most important manufacturer of the inorganic pigment ultramarine blue, as well as producing organic intermediates and various dyes, including eosin, chrysoidine, Bismarck brown (the last three originally associated with Caro at BASF), oranges, and nigrosines. August Merz had served since late 1926 as president of the Synthetic Organic Chemicals Manufacturers' Association (SOCMA), where Calco's Colonel William S. Weeks served on the crudes and intermediates section. The Merz brothers, August and Eugene, joined the growing list of Calco officials. August Merz remained active at American Cyanamid until well into his eighties.

Calco Chemical Company Officials in 1930

President: Robert C. Jeffcott
Vice presidents: George A. Berry; F. Miller Fargo Jr.; J. O. Hammitt; August Merz; and Eugene Merz
Treasurer: C. B. E. Rosane
Secretary: William S. Weeks
Works Committee: John H. McMurray, Victor L. King, and R. M. Taylor

Heller & Merz was followed with the acquisition in January 1931 of another firm that supplied the paper trade, National Ultramarine Company, of Cincinnati, whose production facilities were transferred to Newark. Ultramarine and, later, titanium dioxide pigments were the main inorganic pigments marketed by Bound Brook; an Ultramarine Laboratory was set up in the 1930s. Also acquired in January 1931 was A. Klipstein & Company, of New York, manufacturer and distributor of sulfur blacks, vat and other dyes, varnish, gums and tanners' supplies. In some cases, only specific trading areas and production units were purchased, such as, in 1932, the alkali blue businesses of Zinsser & Co. (February), and Adco Color Corporation (November). Later these operations were moved to Bound Brook.

Three important American Cyanamid acquisitions during March 1930 were not in the dyes sector. These were Lederle Antitoxin Laboratories of Pearl River, New York, Davis & Geck, Inc., of Brooklyn, and the Chemical Construction Company, of Charlotte, North Carolina, manufacturer of synthetic ammonia and methanol, and of chemical plant. Lederle specialized in biomedical products, and in 1922 had begun research and development into pharmaceuticals.[39] Through Calco and Lederle the 1930s would witness a marriage of chemistry and pharmacy based on "Calco's experience in organic synthesis and Lederle's knowledge and technique in biological chemistry, pharmacology, animal testing and established clinical contacts." Davis & Geck was also active in the field of biologicals and, with Lederle, foreshadowed American Cyanamid's later move into pharmaceuticals and eventually the life sciences. Chemical Construction Co. soon became involved with Calco activities at Newark. Chemical Construction, once merged with Cyanamid's Chemical Engineering Corporation, and known as Chemical Construction Corporation, provided a comprehensive service in the design and erection of heavy chemical plant.[40] The specialized process design and engineering construction capabilities enabled American Cyanamid to offer turnkey operations ranging from the processing of petroleum oils to bulk chemical production.[41]

Though Calco felt the impact of what was to become a decade-long recession, it emerged relatively unscathed from this period through the security offered by American Cyanamid, successful commercialization of new innovations, growing strength in the dye market, and the powerful character of its main founder, the autocratic Jeffcott. American Cyanamid was moderately generous in apportioning profits, as a letter from Jeffcott to one of his senior officers, probably McMurray, suggests:

Dear Mac,

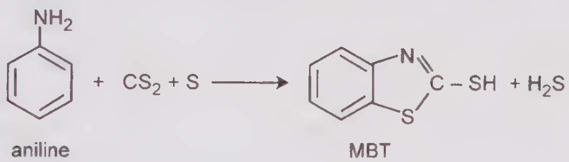
Thanks to Cyanamid's adopting a particularly favorable basis of figuring for us, we have a dividend for 1932. We are surely fortunate to have any, considering business conditions of the past year.

Because of the limited amount the number of participants has been curtailed; and therefore you will realize it is more important than ever that you mention to no one either the fact that you participate or the amount of the attached, which I am very glad to see you get.

It will serve as an illustration of what a good year could bring us! I can see no basis for expecting 1933 to continue as at present, but here's hoping![42]

Jeffcott remained firmly in control at the much-enlarged Bound Brook, even well outside the factory walls. Calco's president had a large yacht, and it was not unusual for him to use it for both business and pleasure. "In the past few weeks a number of Calco men have enjoyed the hospitality of Mr. and Mrs. R. C. Jeffcott at Boothbay Harbor, Maine, and all report an excellent time. Much of the time was spent on the 'Starling.'"[43] According to Jay Leavitt, Calco's president "invited senior staff to spend their vacations [on the *Starling*] in order to discuss business." Moses Crossley, whose summer home was at Martha's Vineyard, was also a sailing enthusiast, as was William Bell, whose *Elena* had in 1928 won the New York to Santander race.

Dye and biomedical firms were only part of the story of diversification. Important large-scale new uses were found for the coal-tar intermediates. The growth of the automobile industry—there were over 29 million vehicles (25,670,000 passenger cars and 3,984,500 trucks) on American roads in 1929—and its demand for long-lasting, chemically resistant rubber products provided a new branch of business for Bound Brook aromatics, particularly aniline and beta-naphthol. This followed George Oenslager's discovery in 1906 at Diamond Rubber that aniline, its derivative thiocarbanilide, and related chemicals accelerated the vulcanization of rubber. "Among the first customers of Calco's aniline was a rubber manufacturer who purchased the product for the production of an accelerator." This was probably Goodyear Tire & Rubber Co., which for some years "had been purchasing aniline from Calco for such manufacture."[44] In 1933, Bound Brook began the manufacture at elevated pressure of the rubber accelerator mercaptobenzothiazole (MBT), from aniline, carbon disulfide, and sulfur, and late in 1936 introduced mercaptobenzothiazyldisulfide (MBTS). Calco was soon satisfying Goodyear's requirements for both products. Subsequently, Goodyear dropped its own manufacture of these accelerators. Zenite ultra-accelerators, incorporating zinc, and that brought about vulcanization in a few minutes, were introduced in the late 1930s. Beta-naphthol was sold in the rubber field to produce an antioxidant. By 1940, these had helped to enlarge the range of Bound Brook products to over 400 finished items. (Most rubber chemicals were produced at Bound Brook, though a few items were manufactured at Warners. From 1940, Calco made thiourea from calcium cyanamide prepared in solution at Warners.) In 1943 the rubber chemicals section became Department R; three years later Goodyear was no longer the main customer.



Manufacture of mercaptobenzothiazole (MBT)

The Selden Company, whose phthalic anhydride was used in the manufacture of vat dye intermediates, became during the late 1920s the largest producer of plasticizers for the growing synthetic resins industry in the United States, through conversion of phthalic anhydride and phthalic acid into phthalic esters, particularly dibutyl phthalate. Phthalic anhydride was also important in the production of alkyd resins, introduced by General Electric in 1929, as glyptals (see chapter 4). These were followed by American Cyanamid's Rezyls and similar DuPont products. Alkyd resin manufacture, however, was constrained by uncertainties related to patents, at least until early in 1931, when General Electric, American Cyanamid, DuPont, and Ellis-Foster Co. (that controlled the inventions of Carleton Ellis, and in which American Cyanamid had an interest) came to an agreement whereby alkyd resins were freed from patent restrictions and all these parties were guaranteed immunity from prosecution.

Following Calco's lead and growth, Bound Brook and environs became increasingly a center of chemical manufacture, joined in 1929 by the asbestos manufacturer Johns-Manville, Inc., located to the west of Calco, and the Bakelite Corporation, which announced plans to move to Bound Brook in the same year.[45] Molded products and components made from Bakelite resin incorporated Calco pigments and dyes: Nigrosine for telephones, Remington typewriters, cigarette cases, and pencil barrels; and green dyes for the Charles Arnao hair-drying hood, mechanical pencils, and caps for containers.

An American Leader

This broadening of operations through horizontal expansion and rapid diversification was facilitated by unprecedented demand for American Cyanamid's potassium cyanide, used in the quite-unrelated activity of gold extraction. Haynes observed that the

> chemical industry realizes the value of its wide and varied markets and it remembers proudly that during the 1930s it earned the adjective "depression proof." During those difficult years when fertilizer demand all but evaporated, the sale of cyanides to the busy gold miners more than kept Cyanamid going. It was cyanide profits that supported the price of the Company's securities so that Bell could economically finance diversification by exchange-of-stock for the purchase of other companies.[46]

This included additional firms involved in manufacture and marketing of dyes and textile chemicals, and even a certain level of vertical expansion.

The E. C. Klipstein & Sons acquisition in 1933 was important for its processes, products, marketing, and personnel. Ernest Christian Klipstein of Marshall, Virginia, had met August Klipstein in the 1880s through a chance encounter. Ernest's sister had sent a pair of spectacles to New York for repair, and they were returned by mistake to the address of August Klipstein, an importer of chemicals, in New York. Through the ensuing correspondence they learned that they shared a common great-great-great grandfather in Germany. Ernest joined August in New York, and in 1888 they secured the agency for the CIBA forerunner, of Basel. In 1890, A. Klipstein (from 1894, A. Klipstein & Co.) started to produce chemicals with the Bulls Ferry Chemical Company, Edgewater, New Jersey. The relationship between Ernest and August became strained at the beginning of World War I, when August sided with the Germans and Ernest with the

Principal acquisitions, including production units, subsidiaries, and affiliates, American Cyanamid Company, as at mid-1930s[47]

Adco Color Corporation
Amalgamated Phosphate Company (fertilizers)
American Powder Company (explosives)
Beaver Chemical Corporation
Beetleware Corporation
Calco Chemical Company
Catalytic Process Corporation
Chemical Construction Company
Crown Chemical Corporation
Davis & Geck, Inc.
Dye Products & Chemical Company
Essex Aniline Works
Filtration Equipment Company
Garfield Aniline Works
Gaskill Chemical Company
General Explosives Corporation (blasting supplies)
Granton Chemical Company
Heller & Merz Company
Kalbfleisch Corporation
Kent Color Corporation
Kerin Manufacturing Company
Klipstein & Company, A.
Klipstein & Sons, E. C.
Laboratory Equipment and Engineering Company
Lederle Antitoxin Laboratories
Ling Chemical Company (sulfur dioxide)
Maryland Chemical Company (heavy chemicals)
May Chemical Company
National Ultramarine Company
Nitrogen Products Corporation
Noil Chemical & Color Works, Inc. (Noil Chemical Company)
Owl Fumigating Corporation (insecticides)
Passaic Color Corporation
Pfister Chemical Company
Rezyl Corporation (synthetic resins)
Selden Company
Southern Alkali Corporation
Southern Chemical Corporation (heavy chemicals)
Structural Gypsum Corporation
Synthetic Plastics Corporation
Textile Chemical Company
Trico Chemical Company
U.S. Tar Products
Wettersol Dyestuff Corporation
Wetterwald & Pfister Chemical Company
Williamsburgh Chemical Company
Zinsser & Company

Allies. They soon parted company, and Ernest established the E. C. Klipstein concern that produced dyes and constructed an electrolytic alkali plant at South Charleston, West Virginia.

E. C. Klipstein & Sons was the first U.S. producer of sulfur black, and an early manufacturer in America of Meldola's blue and of certain anthraquinone vat dyes. The strong marketing capabilities made E. C.

Installation of distillation columns for coal-tar products at Bound Brook, 1935. (Edelstein Library.)

Klipstein an attractive purchase for American Cyanamid's Calco division. The son of the founder was Kenneth H. Klipstein, whose subsequent and successful career was in the employ of Calco.[48] Other acquisitions were: in 1937, H. A. Metz & Co., Inc., of New York, which manufactured and supplied vat and other dyes, and textile and tanning specialties; and in 1938, Amalgamated Dyestuff & Chemical Co., of Newark, producer of sulfur, cellulose acetate, and azo dyes, John Campbell & Co., of New York, manufacturer and supplier of direct, sulfur, basic and chrome dyes, and Russ & Co., of South Bend, Indiana, maker of laundry blue. In all, over thirty American dye firms were merged with Calco.

Vat dye production underwent tremendous growth, since, through Selden's phthalic anhydride capacity and the facilities at Bound Brook, "Calco had a very substantial position in the intermediates for these dyes. Calco thereupon began a program of developing vat dyes rather extensively by the purchase of processes from other plants, both here and abroad, and by the development of its own processes for the manufacture of certain vat dyes." Research into vat dyes at Bound Brook, as elsewhere, soon focused on much needed bright red members that were fast to light and washing, and on solubilization as a means of simplifying the dyeing process. There was considerable diversification in textile chemicals, including manufacture of coal-tar textile assistants, commenced in 1933 and expanded considerably during the rest of the decade. Synthetic tanning, or syntan, chemicals were much in demand as replacements for vegetable products. A number of novel products had been introduced in Germany, particularly at I.G. Farben, around 1930. In 1936, a Calco syntan for the treatment of light-colored leathers was introduced, based on sulfonated diarylmethane derivatives that were also dye intermediates. Calco manufactured the less novel naphthalene sulfonic acid syntans, and dyes for leather. Novel acetate, or disperse, dyes were developed for the new cellulose acetate fiber.

Supplies of coal-tar hydrocarbons often fluctuated. Thus until the early 1930s, naphthalene had been available, duty free, in large quantities from Britain and Germany, but the new synthetic resin and varnish businesses led to a decline in imports from Europe. To ensure a reliable source of aromatics of adequate quality, fractional distillation of coal tar from steelworks' coke-oven tar was commenced at Bound Brook in 1935. The light oil from coal tar afforded benzene, toluene, and xylene, commonly known as benzol, toluol, and xylol, while tar acid gave phenol, cresols, and naphthalene.[49] From 1935, the important naphthalene-derived intermediate Tobias acid was made in a new and enlarged plant at Bound Brook; the process consisted of sulfonation of beta-naphthol to afford Armstrong acid, which was then aminated (amidated). It had been in use at Bound Brook since the 1920s, and Crossley had undertaken research into improvements. In this way, Calco managed to integrate at a single facility most operations required to manufacture aromatic chemicals. As railroad tank cars containing raw, crude coal tar rolled into the factory they passed boxcars loaded with intermediates and finished dyes and rubber products that were departing. From the mid-1930s, Crossley and research chemist L. M. Shafer developed the Calcofast metallized wool dyes, in which the color was determined by the nature of the metal (mainly chromium) or a mixture of metals. Metallized dyes of this type had been introduced just before World War I in Switzerland.

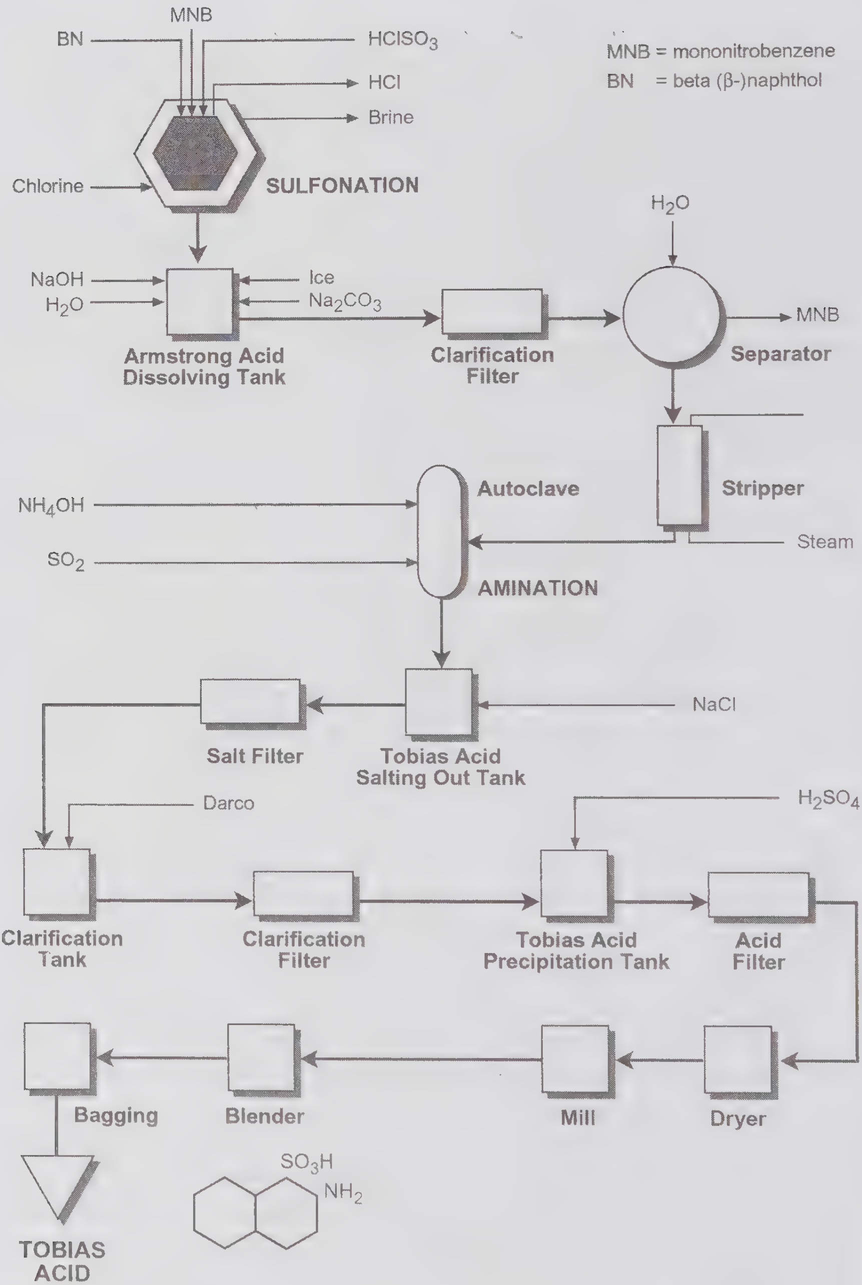
Particularly striking was the proliferation of sections, each with a specified function, which in 1935 included divisions, departments, shops, laboratories, etc. The manufacturing departments, all supplied with laboratories, were: A-1(intermediates; including aniline and beta-naphthol); A-2 (intermediates); E (basic and azo dyes); F (lakes, laundry blue, and Tobias acid); G (vat dyes); H (sulfur colors, stilbene derivatives); I (inorganic acids); and N (originally C, nigrosines; from the mid-1930s incorporating the distillation of coal tar and solvent recovery). Changes took place as products were moved from one department to another. There was also the Research Department, with its Research Laboratories, the Application Laboratory (which included dye testing by specialist colorists, such as William H. Peacock), the Instrument Division, the Power Division, the Tabulating Division, the Physics Department, the new Pharmaceutical Department, the Engineering Laboratory, the Construction Department, and "shops" for "Sydite," aniline oil, DMA (dimethylaniline), and naphthalene.[50] No less essential to the efficient working of the factory were the service, maintenance, sales, central typing, accounting, and traffic departments, along with Methods Engineering, laundry, etc. E. J. Dempsey was works manager, McMurray assistant general manager, and Crossley head of research staff. Calco's operations included manufacturing plants in Charlotte, Damascus (Virginia), and Newark.

To accommodate the wide range of activities, much of the Bound Brook site was reconstructed in the early and mid-1930s, based on a standardized, clean, and functional architectural design inspired by the buildings originally erected at the West Works, that permitted "maximum flexibility with reference to general arrangement, height, width and length and ... a pleasing architectural appearance." For high-pressure reactions, American-made 2,000-gallon welded autoclaves replaced previously imported 300-gallon cast steel reactors. The main expansion program took place during 1932–36, and included four large new buildings, numbers 61, 62, 63, and 66, and a maintenance building. Three high-pressure boilers were installed in the coal-fired power station to supply additional steam and electricity. General progress at Bound Brook was reported in the newspaper

Calco Diamond, "Devoted to the Employees' Interests, Cooperation and Safety," first published in 1935. The inaugural issue only was called *Calco Reactions*. This publication served to bring the growing number of employees together, with descriptions of conviviality and dinners, tips on safety, articles proclaiming the virtues of capitalism, and notes on births, marriages, scratches on automobiles in the parking lot, fishing and vacation trips, and bowling and bridge tournaments, including with nearby Bakelite. There were also condolences to family members of those who died in the line of duty, occasionally following an industrial accident. The year 1935 also saw the founding of the Calco Federal Credit Union, which still trades, now at East High Street, Bound Brook.

The Calco research notebooks reflected the research projects that various processes, products, and applications generated. These included coal-tar distillation, a detailed re-examination of the reaction for fuchsine, or aniline red (by oxidation with nitrobenzene), applications of dyes, and comparisons with competitors' products. To staff the factory's laboratories, Jeffcott inaugurated training programs "for carefully screened recent college graduates" who joined Calco's Student Training Group, and "also sponsored chemical scholarships at Yale to insure the availability of trained personnel." Thus Robert P. Parker was a 1932–33 Calco fellow at Yale, where he received his Ph.D. in organic chemistry in 1933. He immediately joined the Calco Research Department, where in 1938 he was appointed a group leader. Chemists interviewed for this study emphasize that there were many "Yaleies" at Calco. Some suggested that there were times when the facility was run as a fiefdom, based on clubby college backgrounds, and later by a "Princeton Mafia."

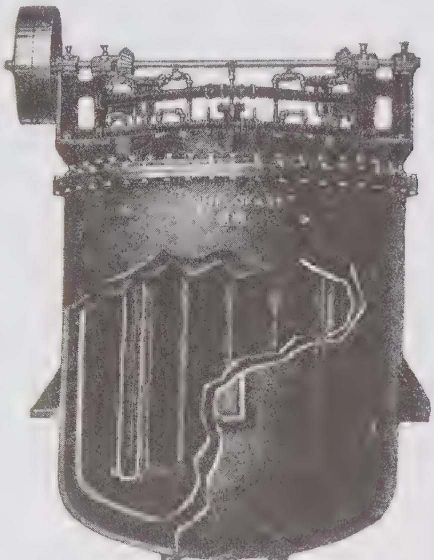
The rapid and efficient supply of information was ensured by the dedicated and enthusiastic custodian of the library, Elizabeth (Betty) Joy Cole. Even leisure time did not prevent her from pursuing professional duties. As well as visiting friends in Virginia one week, she made a point of spending "several days in New York State where she inspected the library of the Taylor Instrument Company, the library and laboratories of the Eastman Kodak Company, and the library and plant of the Corning Glass Works." She also admired the outside of the Cornell Library, though she informed *Calco Diamond* readers that "it was too late to get in."[51]



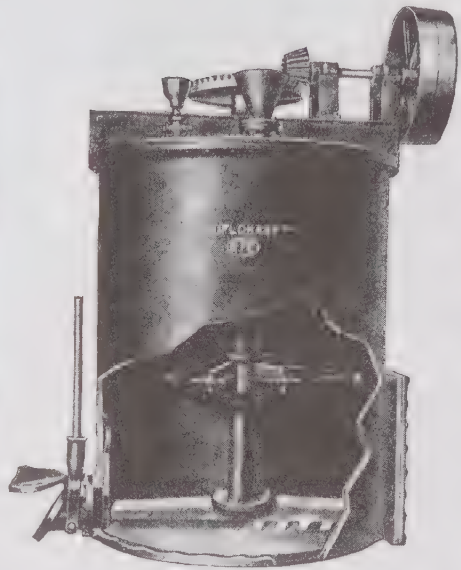
Tobias acid process, Bound Brook

sulfonation. The substitution of one or more H by one or more $—SO_3H$ groups. direct- The treatment of an organic compound with fuming

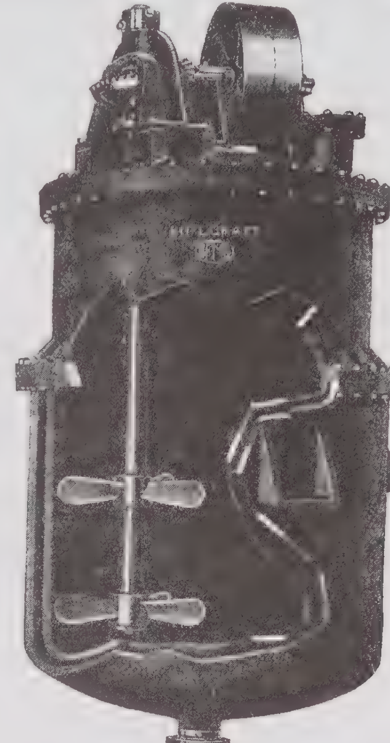
nitrator. A vessel, usually double-jacketed, with or without heating or cooling coils and stirring device, used for nitration.



Nitrator.



Reducer.



Sulfonator.

Typical reactors, manufactured by Buffalo Foundry and Machine Co. ("Buflokast"), for nitration, reduction, and sulfonation. (*Hackh's Chemical Dictionary*, 3rd edition, revised and edited by Julius Grant [London: J. & A. Churchill, 1944], 573, 728, 818. Reproduced with permission of The McGraw-Hill Companies, copyright 1944.)

Interior of azo dye manufacturing building at Bound Brook, 1940. Note the raised wooden diazotization tubs, filter press in the foreground, and the protective clothing worn by workers. (*Dyes Made in America, 1915–1940* [Bound Brook: American Cyanamid Company, 1940]/Edelstein Collection.)

The library had started in 1915 as a collection of scientific and technical books, probably without any form of staffing. Cole, a graduate of Sweet Briar College, joined Calco in August 1930 and with one or two colleagues inaugurated several important functions, including literature reviews (of more recent publications) and surveys (of older publications). Abby Nies was involved in literature searches and studies needed for patent applications, which she carried out from

1938 until the early 1970s. From around 1937, the library was housed in the then new building 10.

An important but separate section was Technical Files in building 40, the repository of internal reports and research notebooks, supervised by Mildred Stewart. Here copies of surveys could also be consulted, including the investigation reports (I.R.s). Typical was M. E. Fitzgerald's 453-page survey of patents and literature on "benzanthrones, dibenzanthrones, isodibenzanthrones, their derivatives and substitution products," prepared to assist Department G, vat dyes.[52] The first member of this group was obtained in 1904 by Oscar Bally when applying Zdenko Skraup's synthesis, that is, treatment of an aromatic amino compound—in this case beta-, or 2-, aminoanthraquinone—with glycerol and sulfuric acid in the presence of an oxidizing agent. From 1920, the reaction was used in the manufacture of Jade Green. Calco expertise in literature surveys and in the latest instrumental methods would be reflected in the various review articles prepared by its scientists for text books and learned journals.

The library employees helped compensate in many ways for lack of written and spoken communication skills among newer members of the scientific and technical staff. This was a cause of concern for Victor King: "One of the most outstanding faults, if one is looking for faults in the young men, is their inability to use the English language. The writing of simple reports and the expressing of themselves verbally seem to be two things in which they are notably deficient."[53]

A Maturing Business

Mergers, integration, and consolidation, often involving sectors whose only relationship was that they engaged in chemical manufacture, characterized the growth of the U.S. chemical industry during the 1930s. Competition was minimal, not so much because of trust formation, which was illegal, but because of orderly agreements over "spheres of interest." While this did not go unnoticed, it did not trouble the Republican administrations of the 1920s and early 1930s.[54] American Cyanamid controlled dye prices jointly with DuPont and other firms, including Allied Chemical & Dye, and the

Cincinnati Chemical Works owned by CIBA, Geigy, and Sandoz. Such comfortable arrangements enhanced the wealth of the chemical companies and enabled them to set up headquarters in the most prestigious locations, particularly the latest skyscrapers. In 1934, American Cyanamid chose the top floors of the brand-new 70-story RCA Building (now GE Building) at 30 Rockefeller Plaza, on Fifth Avenue, in midtown Manhattan. Designed by Raymond Hood and others, its flat roof and strong vertical lines, and the striking combination of Indiana limestone, brick, granite, and steel, were imitated by the other buildings that made up Rockefeller Center, of which it was the centerpiece, as well as a prominent feature of the New York skyline. Appropriately, the RCA Building was also home to the New York Museum of Science and Industry.

From the mid-1930s, American Cyanamid's sales were aided by slick marketing, particularly outstanding advertisements that carried a message rather than a list of chemicals, inspired by the chemically trained consultant Carl Hazard and his creative team of artists and designers.[55] Striking pictorial advertisements—instead of masthead bird's-eye views of factories—represented a new trend in the promotion by chemical companies of their products, most of which were not supplied to the public but to other manufacturers. For many years, and well into the 1940s, American Cyanamid ran two-color double-spread advertisements headed "Life ... on the Chemical Newsfront," with photographs and brief descriptions of applications of its various products, in *Chemical Industries*, and similar advertisements in other trade journals.

The Sales Department included Fargo, Moody, and, during 1934–39, MIT graduate Harold E. Thayer, who sold Calco's colorants to dye and printworks in the New York and Vermont districts. Among the novel sales gimmicks introduced in 1938 were samples of fabric colored with azo dyes cut out in the shapes of animals, placed in "a circus," that "brought life and human interest into the swatches." Thayer, tiring of the frequent long-distance traveling, and no doubt also with carrying around heavy swatches and samples, joined Mallinckrodt Chemical Works in 1939, where he later became president.

DuPont also diversified, as did Allied Chemical & Dye, and Union Carbide & Carbon Corporation (that acquired Bakelite in 1939). These were the national leaders, followed, at a distance, by

American Cyanamid. It was Calco's growth that enabled American Cyanamid to become the fourth largest and certainly most diversified chemical company in the United States.[56] By the late 1930s, according to an internal I.G. Farben survey, DuPont, Allied, and Calco each produced about a quarter of all dyes sold in the United States. General Aniline Works (GAF from 1939), Dow Chemical Company, and the Cincinnati Chemical Works accounted for a further 20 percent, and some 90 other firms for 5 percent of sales.[57]

The various Cyanamid acquisitions, including Calco, had been enabled by unusually great confidence shown in Bell from leading New York investment banks. No doubt this was facilitated by James Duke's earlier substantial investments in American Cyanamid (Duke died in 1925). Certainly, backing from Wall Street was still unusual for the chemical industry, even in the 1930s.[58]

From 1933 the ongoing recession and European events raised the specter of large-scale national planning and government control. After the Democrat Franklin Delano Roosevelt defeated Republican Herbert Hoover in November 1932, he almost immediately inaugurated New Deal measures, interpreted by many as state control and condemnation of free-market business management. In the eyes of industrial leaders, the National Industrial Recovery Act of June 1933, while encouraging the purchase of American-made goods (as did the Buy America Act, passed in March, and the depreciating dollar, after the United States was taken off the gold standard in April), was tainted with an excess of authoritarianism.

Bell, as president of the Manufacturing Chemists' Association (1933–36), and a staunch Republican, certainly had American Cyanamid's interests in mind as he lobbied with members of the association against criticisms of bad management and any form of control. His main concern was with the impact of planning on agriculture and related businesses, and his sentiments echoed the fears of, and found a strong following among, industrialists.[59] Bell's response to the perceived threat, exemplified by Soviet Russia, was presented before the 1935 general meeting of the American Chemical Society held in New York, an event that celebrated the tercentenary of the founding of the U.S. chemical industry.

What is the favorite panacea? We have had a number, but the favorite panacea today is national planning. It is a magic word. Everybody leaps at once to the idea of national planning. Why? Well, because we have listened so frequently to the charge that business planning has been a complete failure. It is said that we designed too many plants, we have created too much overcapacity, and now, as a consequence, we are compelled to grind the faces of labor, to rob the consumer, to bear down on stockholders and bondholders in an effort to carry dividends and interest, what we can of them, on these great investments. And, as a result, business has been indicted, tried, convicted of this great crime of bad planning.[60]

Similar sentiments appeared in the *Calco Diamond*, including Calco vice president August Merz's description of conditions in Russia, and an item headed "Share the Wealth?"[61] American Cyanamid vice president Lewis Douglas, former director of the federal budget, mimicked Bell when addressing the annual meeting of the Manufacturing Chemists' Association, in June 1935.

Outside of the Soviet Union, businesses collaborated to moderate markets, either through lobbying for tariffs on imports or by controlling both prices and production. During the 1930s, the European chemical industry fostered protectionism through international dyestuffs and nitrogen-products cartels. American firms were self-excluded in the main by concern over violations of the Sherman Anti-Trust Act. They relied on technology-sharing agreements, introduction of federal tariff barriers, and more discrete price-fixing arrangements, though they did sometimes collaborate with the European cartels in certain non-U.S. markets, such as the Far East. American Cyanamid and I.G. Farben were partners in the international sodium cyanide convention, and other arrangements, some through the direct involvement of Bell.[62] No doubt this link with Germany's largest chemical corporation explains why during the mid-1930s American Cyanamid executives appear to have refrained from criticisms of the Nazi dictatorship.

Protection for domestic production in the United States was aided by the Smoot–Hawley Tariff Act (1930)—by 1933 it had imposed an average tariff rate of 59 percent on dutiable imports—and non-competition arrangements between manufacturers, "in a manner that would please even a Soviet Commissar."[63] Through their American manufacturing operations, the three main Swiss firms (owners of

Cincinnati Chemical Works) and the German behemoth I.G. Farben (that owned General Aniline Works) were not subjected to customs duties, and were enabled to compete or collaborate on equal terms in the colorant business with DuPont, Allied, and Calco.

The close-knit foreign cartels certainly made life difficult for American firms, including American Cyanamid, anxious to engage in technical exchange programs, and strategic alliances, particularly in coal-to-oil (hydrogenation) and polymer processes. At the end of the 1930s, even straightforward technical exchanges were often viewed with suspicion. Robert Jeffcott, in an attempt to bring about collaboration between Calco and European firms that were believed to be outside the I.G. Farben-controlled dyestuffs cartel, embarked on what in hindsight appears to have been a somewhat quixotic campaign. He visited, in addition to other concerns, the Aussiger Verein (Verein für Chemische und Metallurgische Produktion in Aussig) in Prague, and Chemische Fabrik Rohner AG in Pratteln, Switzerland. These firms were solid members of the German-controlled cartel. However, they did not let on their involvement in it. Rohner passed on to I.G. Farben details of Calco's interest, that in 1940 were brought to the attention of the Reich Ministry of Economics.[64] Jeffcott also visited ACNA (Azienda Colori Nazionali Affini) in Milan, which had been identified as a member of the dye cartel by the Chemical Division of the U.S. Department of Commerce (ACNA was 51 percent owned by Montecatini, and 49 percent by I.G. Farben). Jeffcott was probably accompanied by Victor King and other Calco technical people, as well as by Cyanamid vice president Walter S. Landis, who in April 1939 presented his impressions of Italian and German chemical industries in a paper, "Fascist *vs.* Democratic Chemical Industry," before the American Chemical Society's Division of Industrial and Engineering Chemistry.

More Calco People: Early Developments in Instrumental Analysis

Diversification and expansion in dye production and rubber-processing chemicals during the 1930s meant that experienced research staff were required at Bound Brook. Richard Herrlinger, formerly assistant chemist at I.G. Wolfen (AGFA) in central Germany (1922–24) joined Calco's Research Department in 1930; in 1934 he was promoted to a research group leader, and in 1938 joined the Selden Bridgeville facility. James Kenneth Dixon (Ph.D., Yale, 1929) was taken on as a research chemist in 1933, after a few years in Yale's Sterling Chemistry Laboratory. Organic chemist Harold Talbot Lacey (Ph.D., Cornell, 1926) joined the Research Department in 1932, after three years at Grasselli Chemical.

In 1934, King took on Hans Zacharias Lecher, formerly of I.G. Farben's rubber-manufacturing facility at Leverkusen (1927–32), to work in the Research Department. Lecher, born in Vienna in 1887, obtained his doctorate in organic chemistry at Munich in 1913 under Heinrich Wieland (1927 Nobel Prize laureate), and taught at Freiburg during 1922–27. According to Erwin Klingsberg, Lecher "was a chemist of the old school, from the heroic age of organic chemistry, and knew Adolf Baeyer in Munich." Lecher, incidentally, had made a hasty exit from Germany in the early 1930s, not because of any political convictions, but because he had run off with the wife of a senior colleague. They were later married in New Jersey.[65] Lecher became a citizen of the United States in 1940.

Other organic chemists had a decade or more of prior industrial experience in the United States, though rarely in the dye industry. Rubber chemist Norman A. Shepard (Ph.D., Yale, 1913) had worked for Firestone Tire & Rubber during 1919–36 before joining Calco in 1936. In 1941, he was promoted to chemical director at the New York offices of American Cyanamid. Another expert in rubber chemistry who joined Bound Brook in 1936 was Arnold Rogers Davis, who had previously worked at Firestone Footware Co., and U.S. Rubber Co. He contributed considerably toward the development of Calco's rubber-processing products. During the mid-1930s, Alling Beardsley was closely involved in the work of the Research Department.

In general, new entrants into Calco's Research Department, or into manufacturing departments as research chemists—generally assigned to dyes—during the 1930s were young men in their twenties, with sometimes a few years experience as teaching assistants or in industry, and—less rarely than before 1914—with a year or two in a German or other European laboratory. Those joining Bound Brook on completion of their Ph.D.s included, in addition to Parker, Alfred

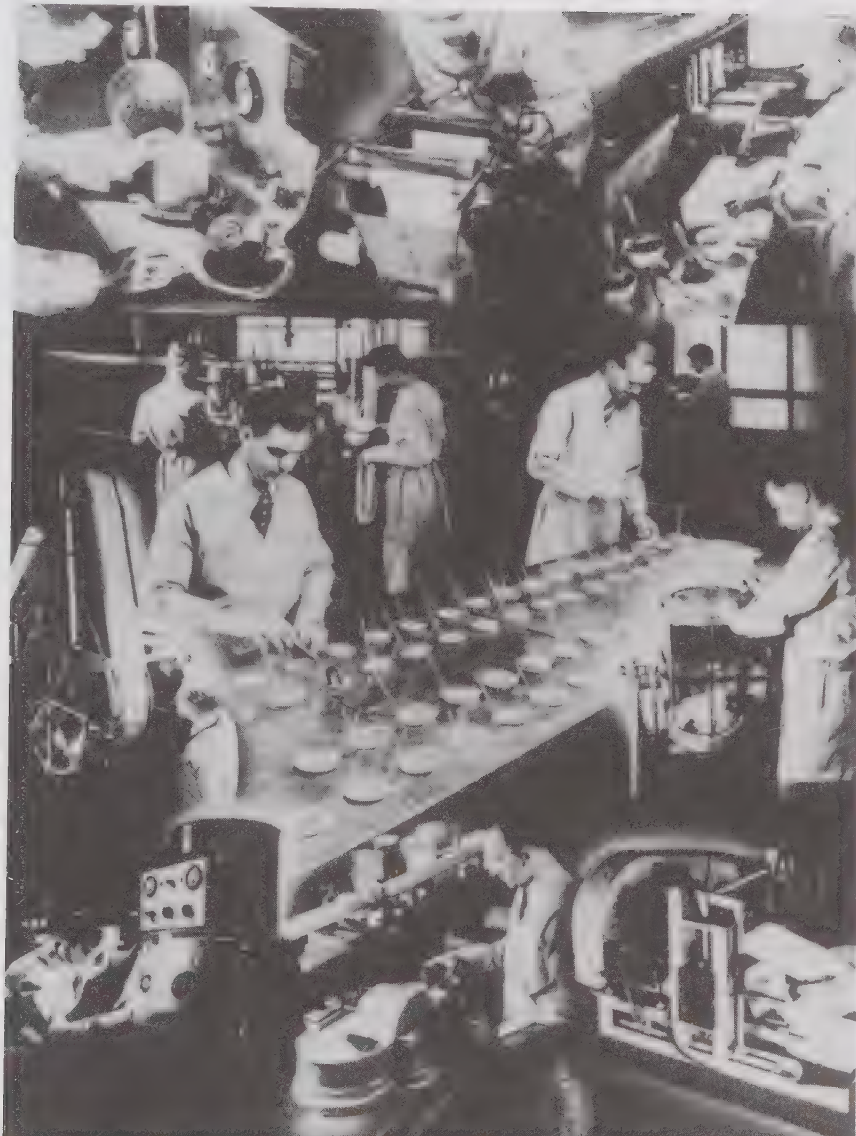
Louis Peiker (McGill, 1930, physical chemistry), A(lfred) Garrett Hill (Yale, 1932), Dale Raymond Eberhart (Ohio State, 1935), Martin Everett Hultquist (Colorado, 1935), and Mario Scalera (Yale, 1935).[66] Other research chemists at Bound Brook with Ph.D.s were Elmore H. Northey (Minnesota, 1930), who joined Calco in 1932, Frederic Henry Adams (Princeton, 1933), and, from 1936, Glenn S. Watson. Apart from Peiker, they undertook research in synthetic organic chemistry. Northey and Hultquist soon became involved in pharmaceuticals. Several research chemists advanced to positions as chief chemist with a production department, senior research chemist, group leader or research manager, assistant to a research director, research director, and then, according to organizational ability, to senior management posts in research, production, marketing, and service divisions. Scalera, born in Naples, Italy, in 1909, was appointed a group leader in vat dye research in 1939, and eventually became an administrative director, as did Northey, Parker, and Peiker. Adams, who was born in Beirut, Lebanon, in 1902, specialized in azo dyes. In 1937–38, his research assignments included analysis of I.G. Farben's Rapidogen dyes—introduced from 1930—that were used in printing on cellulose-based fabrics and were noted for their ease of use and fastness. Adams was appointed assistant chief chemist in 1939, and research associate in 1951. Watson was later promoted to assistant chief chemist and then chief chemist.

A number of newly arrived chemists entered straight into production roles. They included Wendel B. Munro, who received his B.S. and M.S. in chemical engineering from the University of Iowa, and Ph.D. in chemistry from Princeton in 1932. He was a DuPont postdoctoral fellow at Princeton during 1932–33, after which he joined Calco, at first in Department A, soon moving on to Department G. He later became assistant chief chemist in the organic section of the Research Department.

In 1937, a new organic chemist in Lecher's group was Neil M. Mackenzie, who, like Hill, Parker, and Scalera, arrived direct from Yale's Sterling Chemistry Laboratory on completion of his Ph.D. Early in June 1937, just prior to joining Calco, Mackenzie was advised by Lecher: "The general field of your work has not been decided yet. However, when you have spare time it might be a good idea to make yourself somewhat acquainted with the chemistry of dyestuffs."[67] Mackenzie, in common with many others mentioned here, was to become a long-serving member of the Calco staff.[68] His later posts included senior research chemist, staff assistant, R&D (1964), and business manager, R&D (1967).

No less important than synthetic organic chemistry were studies into textile coloration and standardization of dyes. These, activities—central to the routine work of the Application Laboratory—were notable features of Bound Brook research, drawing, from 1930, on a mix of instrumental methods, the physics of color, and physical and organic chemistry. Much of the research followed major theoretical advances during the 1920s by Erwin Schrödinger and others in the classification and measurement of color; the adoption in 1931 by the C.I.E. (Commission Internationale de l'Eclairage; also known as the International Commission on Illumination) of the "standard observer," and the XYZ coordinate system of color specification based on three well-chosen lights, the basis of tristimulus colorimetry; and the introduction during the early 1930s of the spectrophotometer and other novel instruments into industrial research laboratories. At Bound Brook, instruments were modified to enable a better understanding of, and improvements in, dye application, and facilitated pioneering studies on quantitative measurement of color. By the early 1940s, the latter work permitted precise and rapid instrumental matching of shades, replacing dependence on the eye and observation of samples under different lights. The first step leading toward these innovations was organization of a team of specialists familiar with instruments and color physics as a dedicated physics research group. German-born Robert H. Park, a physicist previously employed in industry, including at General Electric, was taken on in 1931 to head the physics research in building 41. Several physical chemists joined the ranks of organic chemists engaged in dye research; fundamental studies on color and constitution were undertaken, often with modified commercial and homemade instruments.

George Lewis Royer (B.S., Akron, 1929; Ph.D., Cornell, 1932) joined Calco in 1932, and undertook investigations into the applications of dyes to a variety of fabrics using microscopy and microchemistry, before turning to other instrumental methods. These and similar endeavors led to improved dyeing processes, such as, in 1938, Ormand W. Clark's method of dyeing cotton yarn with vat colorants



Application laboratories, Bound Brook, 1940. The montage shows a variety of activities, including measurement of color, determination of fading characteristics, and dyeing experiments. (*Dyes Made in America, 1915–1940* [Bound Brook: American Cyanamid Company, 1940]/Edelstein Collection.)

that gave improved uniformity of color. Chester Albert Amick joined Calco's Research Department at the age of 40 in 1935, following several years as a chemist in the dye-using industry at, successively, Pacific Mills, Massachusetts, U.S. Finishing, Providence, Rhode Island, and Glenlyon Print Works, Phillipsdale, also in Rhode Island. Amick undertook research into the processing of cellulosic fabrics, and the dyeing and printing of cotton and wool. During 1939–40, Royer served as an officer of the American Chemical Society's Section of Analytical Chemistry of the Division of Physical and Inorganic Chemistry, and in September 1940 was appointed vice chairman of the section's successor, the Division of Analytical and Microchemistry.

Not all research chemists, particularly those involved in the newer physical methods, possessed doctorates. Specialist knowledge or achievement in industry were more than adequate substitutes. Edwin Ira Stearns joined Calco in 1933, in which year he received the M.S. in physical chemistry from Rensselaer Polytechnic Institute; his bachelor's degree, majoring in chemical engineering, was from Lafayette College (1932). Stearns became an outstanding leader in chemical spectroscopy who contributed to many scientific and technical publications. In 1934, the 38-year-old alkyd resin specialist Roy Herman Kienle arrived from General Electric, where, apart from two years in the Chemical Warfare Service (1917–19), he had worked since 1916, and in 1919 was appointed research chemist. At Bound Brook he served at first as research chemist and chief physical chemist (1933–36), and then as assistant research director (1936–39), making notable studies on the dyeing of wool.[69] His work on synthetic resins is discussed further in chapter 4. Stearns and Kienle would study for their doctorates, both in physical chemistry at Rutgers, while in the employ of American Cyanamid.

General Electric manufactured the first successful spectrophotometer, based on the work of Arthur Cobb Hardy at MIT. Orrin Weston Pineo, an MIT graduate (B.S., majoring in physics, 1929) who had worked with Hardy on the spectrophotometer (1929–33), and with Adam Hilger Ltd., in London, on an automatic spectrophotometer (1933–34), joined Calco in 1935 and adapted instruments to color analysis in dyeing (see chapter 5).

Stearns's contributions commenced in 1933–34, when he adapted instrumental colorimetry to checking the blending of intermediates. Colorimetry involves comparing light transmitted by a solution with that transmitted by a standard solution, or measures light energy absorbed by a solution, that is, photometric measurement, as employed by Stearns. The measuring instrument, the colorimeter, has three or four filters, and detectors, is mechanically simple, and gives rapid results. One blending process involved the highly explosive—when dry—picramic acid (2-amino-4,6-dinitrophenol, produced from picric acid, and used in the manufacture of azo dyes). If sufficiently wet or diluted with salt, the poorly soluble picramic acid was safe to handle. Each batch was checked to ensure that the purity never went beyond about 65 percent. To achieve this, Calco worked a novel "solution-controlled" process. The blending took place in a steel drum, loaded with steel balls to give a grinding action. As a precaution, it was housed in a shed "far away from the plant and having only three sides."

The safety of the process relied on reliable and rapid monitoring. Verification of the method introduced by Stearns and colleagues turned out to be a singularly spectacular event. One day, the colorimeter recorded 90 percent picramic acid—far too dry—much to the disbelief of the supervisor, who decided to disregard the data: "Well, seldom has the correctness of a colorimetric result been verified with such a thunderous acclaim. The blast was heard as far away as East Manville."[70] The outcome was that from 1938, Calco relied on instrumental data for monitoring solution-controlled blending.

These developments at Bound Brook greatly encouraged the wider use of instruments in chemical analysis, color control, and research.[71] Stearns studied instrumental methods for dye standardization and collaborated with Park on color comparisons. The result was that in 1940 the first batch of Bound Brook dye that had been checked without carrying out a dyeing trial left the factory. This was the "first dye lot shipped on the basis of a colorimetric test by any dye company anywhere in the world." It was quite an advance in quality control, particularly since Calco produced such a great range of colorants, including, the firm's publicists claimed, more than 200 distinct blue dyes.

No less significant was the connection with R(obert) Bowling Barnes (Ph.D., Johns Hopkins, 1929), an instructor at the Palmer

Research laboratories, Bound Brook, 1940. Note the various physical instruments. (*Dyes Made in America, 1915–1940* [Bound Brook: American Cyanamid Company, 1940]/Edelstein Collection.)

Physical Laboratory, Princeton, from 1933 to 1936, during which time he undertook consultancy work on infrared spectrophotometry for Calco. Through Barnes's connection with Bound Brook, his colleague R. Robert Brattain, then a graduate student but later a pioneer of instrumental infrared analysis, received support for research from Calco. For a year, starting in January 1937, Brattain spent long periods recording spectral data for aliphatic and aromatic compounds at the Bound Brook Research Department. One outcome was Brattain's first multi-component analysis, in which he confirmed Calco's suspicion that two isomers were present in its cresol (probably from the recently installed coal-tar distillation plant). Brattain joined the Shell Development Company laboratories at Emeryville, California, in 1938. Before leaving Princeton, he introduced to American Cyanamid another graduate student, Van Zandt Williams, who, with Barnes, would within a few years contribute to the corporation's cutting-edge developments in instrumental chemical analysis.[72]

Research *and* Development

Calco's research and production needs were regularly reviewed by a Laboratory Coordinating Committee and a Technical Committee, respectively. Often their activities, and memberships, overlapped, and interacted with the work of other committees, such as the Dye Type Committee. In the mid-1930s, the Technical Committee appears to have served as a general process and product development department, with its own budget allocation, quite separate from the Research Department. While expenditures on intermediate and inorganic acid technical developments in 1935 were minimal, the expenditures on process and product improvements in the main dye classes—azo, vat, lake, and sulfur—came close to that invested in "Direct Research." By the early 1940s, there were eight technical committees, each representing a main product type.

The Laboratory Coordinating Committee was headed by Crossley, and included engineer Don H. W. Felch, Kenneth Klipstein, Lacey, Lecher, Park, and Dr. Roy A. Shive. On April 1, 1936, a small group, including Lacey, Lecher, and Klipstein, gathered to discuss the use of dyes to replace the dry colors and pigments employed in printing inks, as supplied to International Printing Ink Corporation (later Interchemical Corporation), in New York. Initial estimates indicated that "25 percent of the dry colors could be replaced." There was a demand for both "new and rapid drying inks" that were soluble in petroleum solvents, did not readily sublime, displayed a reasonable amount of brilliancy, resisted fading, and were insoluble in water. The growth in demand for printing inks at this time stimulated Calco to embark on large-scale production of azo and phthalocyanine pigments for use in the printing industry, and of other pigments, to supplement the Heller & Merz range, for paper mills. During 1936, Calco's soluble blues used in laundries were losing out to General Aniline's blues "which they make in the U.S.A." and gave more level dyeings. Dr. Crossley advised his committee that a "very serious situation is at hand with regard to the sales of our Soluble Blue Types."

The Technical Committee was headed by Victor King; it included D. M. Aumack, later involved in effluent treatment, Felch, and Shive. In April 1936, the committee considered progress on Fuchsine XX and the yellow colorant Phosphine, both scheduled for transfer from the Heller & Merz facility in Newark. In May, King convened a special meeting to consider the "very serious situation in the Meldola Blue–gallocyanine equipment," that had recently been installed but was already experiencing problems with piping, leaks, and an inoperative impeller of the "nitroso slurry pump."

The Dye Type Committee was chaired by a certain Sampson, and included Aumack, William Goldstein, an organic chemist, Nat Koenigsberg, an expert in color matching, William H. Peacock, and Shive. The work of this committee included review of the weekly letter from the Standards Laboratory, and discussion of how Calco products were standing up to the competition. New forms of existing colorants were much in need, since red pigments were suffering from superior Sherwin-Williams products, and sales of Pencil Violet, particularly to American Lead Pencil, had fallen dramatically. Samples of the Pencil Violet sent to L. and C. Hardtmuth, in Budweis, Czechoslovakia, were found to be of poor quality. Blues were having a particularly hard time, quite apart from the laundry blues. There were complaints of poor quality "Meldola blue" and alkali blue, the latter supplied to the Sleight Metallic Ink Co., of Chicago. Eastman Kodak required a spirit blue, and there was a strong interest in blends to obtain specific shades. Investigation orders (I.O.s) were issued for studies on new and old colorants, including Calco's Permatones, methyl violet, "Fuchsine (rosaniline)," and safranine.

Calco's products and scientific developments were promoted through its Calco Technical Bulletins, the first of which, William Peacock's *The Evolution of Wood Stains*, was issued in August 1937. Many were original publications; others were reprints from articles authored by Calco chemists, including the bulletin by Peacock and, also in 1937, August Merz's *The Sons of Aniline*, that dealt with dyes and the applications of intermediates.[73] The work of Stearns and colleagues received considerable prominence in the bulletins. Other authors included Henry E. Millson, later a technical service expert in the dyeing of wool.[74] Their careers are considered in more detail in chapters 5 and 6.

In 1937, Calco executives included George A. Berry, plant vice president, J. F. Warner, vice president in charge of dyestuffs, F. M. Fargo, vice president in charge of sales, August Merz, plant vice president, Colonel Weeks, secretary and counsel, King, technical director, Crossley, research director, McMurray, vice president in charge of engineering and construction, Carl E. Mensing, chief engineer, Carl M. Bigelow, director of the newly formed Pharmaceutical Department, and Donald O. Hamblin, medical director. It was to be the last year in which American Cyanamid research was the almost exclusive domain of Bound Brook. In 1937, the corporation, whose net profit for the year was $5,268,255, also opened the Stamford, Connecticut, "General Research Laboratories" in a former silk factory. Calco scientists, as if to emphasize their own outstanding role in research among the chemical community, and in particular the role of technology in determining scientific fields of enquiry, made an impressive showing at the American Chemical Society's 93rd meeting, held at Chapel Hill, North Carolina. Crossley, whose interest in education lay behind his talk on "The Inspirational Element in the Teaching of Chemistry," was coauthor of two other papers, one jointly with Kienle, C. H. Benbrook, and E. G. Kelley, on phenyl diazonium chloride, and the other with Byron L. West, Eberhart, and J. C. Milligan, on metallized azo dyes. Kienle and R. Bowling Barnes, the latter then between leaving Princeton and joining American Cyanamid, where he was soon moved to Stamford, spoke on infrared spectroscopy and organic chemistry. Crossley no doubt attended the presentation by Heinrich Hörlein, scientific director of I.G. Farben's "Chemical and Medical Research," on the new sulfonamide drugs, given before the Division of Medicinal Chemistry.[75] Both Crossley and Hörlein had wide-ranging interests in the pharmaceutical products made from dye intermediates. Hörlein had joined Bayer, at Elberfeld, in 1909, and from the late 1920s emphasized that just as the color and other properties of dyes were modified through structural changes, so similar changes were responsible for alterations in the physiological effect of aromatic chemicals. In 1935, the red dye Prontosil, later Prontylin in the United States, was the first major outcome of the endeavor to attack sites of infection within the body with such products.[76]

Chapter 3

"Molding the Future": Sulfa Drugs and Amino Plastics

"The company's faith in research has been vindicated by a series of important discoveries, which have led to the development of new products and processes, many of which have proved to be important contributions to the arts, as well as to the earnings of the company."—"American Chemical Industries: American Cyanamid Company," *Industrial and Engineering Chemistry* 22 (1930): 301–2.

"Molding the Future" was a slogan that accompanied American Cyanamid advertisements in the mid-1940s. It was also the subtitle of Kenneth C. Towe's 1953 account of William Bell's life, given to and published by the Newcomen Society in North America. Certainly it came close to describing one of the firm's main innovative activities that had originated at Bound Brook, the production of novel amino resins used in the manufacture of plastics, laminates, and other surface coatings. From around 1930, plastics aroused considerable excitement, particularly after the new technology of rapid hot molding enabled a variety of intricately shaped artifacts for domestic and other uses to become available at modest prices. No less remarkable were the early sulfa drugs for specific bactericidal use made at Bound Brook.

Though these started out as imitations of European inventions, the American Cyanamid innovations were the outcomes of highly focused research and process development at Bound Brook. Through an external event, the outbreak of war, they soon attracted levels of national and international attention that could not have been achieved by the mature dyestuffs, however colorful and innovative. These new materials and lifesaving chemicals were distinguished in war service, and brought accolades to Bound Brook. Moreover, it is because pharmaceuticals and polymers are two advances most closely connected with the 20th-century chemical industry, particularly the growing equivalence of technology with science during and after World War II, that this chapter is devoted to their developments at Calco.

Sulfonamide Drugs

The large-scale involvement of American Cyanamid in drug development arose from its acquisition in 1930 of Lederle and Davis & Geck, both of New York. Lederle was founded in 1906 by Dr. Ernst J. Lederle, former New York health commissioner. It specialized in biological chemistry, pharmacology, and veterinary products, and from 1913 traded as Lederle Antitoxin Laboratories, Inc. Lederle, whose facilities were located at Pearl River, New York, began to develop pharmaceuticals in 1922. To enable the takeover by American Cyanamid, Lederle Laboratories, Inc., was incorporated on February 8, 1930, in Delaware, to acquire the assets of Lederle Antitoxin Laboratories. In like manner, Davis & Geck, Inc., was incorporated on January 28, 1930, in New York, to acquire the assets of the New York corporation of the same name.[1] These firms played a significant role in the production of bacterial vaccines, particularly for veterinary use, and other biological and biomedical products.[2] By the early 1930s, production of bacterial vaccines was a highly developed technology that owed much to original research sponsored by the Hoechst dyeworks in the 1890s. These vaccines were soon to be joined at Lederle by Calco's coal-tar therapeutic products.

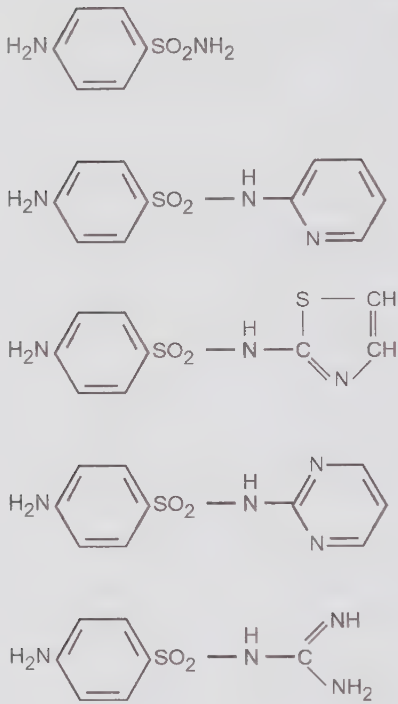
The Bound Brook factory had its own considerable experience in medical products produced from coal-tar derivatives during World War I, including the antiseptics acriflavine, proflavine, and brilliant green. Calco manufactured Cinchophen, which, with its ester, Neocinchophen, were profitable until the mid-1930s, when reports of occasional deaths arising from their uses led to demise. Calco also received a license from the Chemical Foundation to manufacture the local anesthetic procaine hydrochloride, better known as Novocain.

Though extremely useful, the early synthetic, or coal-tar, drugs and medicinal dyes did not attack sites of bacterial infection within the body. The first product to achieve this with any degree of success was Hoechst's Salvarsan, introduced in 1909. It was the original, and only, "magic bullet" of Paul Ehrlich; it took until 1935 before another one became available, again as a result of research connected to the pharmacological use of compounds originally developed as dyestuffs. This second product was the first of the sulfa or "wonder" drugs, discovered at the Elberfeld (Bayer) research laboratories of I.G. Farben, where Heinrich Hörlein was scientific director of pharmaceutical research. In 1932, Gerhard Domagk, director of the laboratory of experimental pathology in the pharmaceutical division, found that a sulfonamide, or sulfamido, compound, a derivative of chrysoidine, an azo dye that had been developed commercially by Heinrich Caro in 1876, was biologically active against streptococcal infections.[3] It was introduced in 1935 as Prontosil.

French workers at the Pasteur Institute discovered during a screening campaign that *p*-aminobenzenesulfanilamide, commonly called sulfanilamide, was an equally effective curative agent. They quickly established that this compound was in fact a breakdown product of Prontosil, formed by cleavage of the azo link when the dye was present in the organism. The preparation of sulfanilamide had been described in 1908, and, therefore, could not be patented. This enabled several companies to undertake its manufacture and engage in research into what became known as sulfonamide drugs. Though I.G. Farben undertook further research, it failed to fully exploit the commercial potential of the sulfonamides. This was left to foreign firms, mainly Calco in the United States, and May & Baker in England.

Calco's Moses L. Crossley started research in June 1936, and a pilot plant for sulfanilamide was erected under the supervision of Elmore Hathaway Northey, an organic chemist with the new Pharmaceutical Division. Northey had joined Calco in 1932, after two years of research at DuPont. His doctoral studies were on absorption spectra of organic molecules, particularly quinones, a topic related to the vat dyes that Calco had recently begun to manufacture.[4] Haynes's description of how they started, even if tempered with a little writer's license, certainly conveys the immediacy of the moment of realization.

When he got a modest budget for medicinal work Crossley did two sensible things. He became a regular reader of *The Lancet* and he brought in a young



Sulfanilamide (1935)

Sulfapyridine (1938)
(M&B 693)

Sulfathiazole (1938)

Sulfadiazine (1940)
(sulfapyrimidine)

Sulfaguanidine (1940)
(sulfanilylguanidine)

The first sulfa drugs

organic chemist, well trained at Minnesota, Dr. Elmore H. Northey, to head up the pharmaceutical research.

Expertly scanning the pages of the famous British medical journal, the morning of June 20, 1936, Crossley was stopped short by an article describing sensational results in treating the deadly streptococcus infection, childbirth fever, with a new drug, sulfanilamide. He recognized it as an old dye intermediate and re-read the article carefully. Then he sent for Northey and silently gave him the magazine. After he had read the article Northey looked at Crossley and both men smiled. Here was something new and important.[5]

Calco's product received an unexpected but very welcome boost later in 1936 after Prontylin, Winthrop Chemical Corporation's name for Bayer's Prontosil, cured President Roosevelt's son of a throat infection. (Bayer had an interest in Winthrop, and through this I.G. Farben gained access to the U.S. pharmaceuticals market). Research quantities of Bound Brook's sulfanilamide were dispatched in the fall of that year, and commercial delivery began in February 1937. Calco was the first American firm to go into production, and by July 1937, output had reached nine tons.[6] Lederle Laboratories became engaged in both research and clinical testing.

The next major discovery was made at May & Baker of Dagenham, Essex, England, where in the spring of 1938, Arthur J. Ewins and Montague A. Phillips synthesized sulfapyridine, soon to be known as M&B 693.[7] Sulfapyridine was independently synthesized by a group of Calco–Lederle chemists, as well as by L. N. Goldirev and I. J. Postovski in the Soviet Union, apparently before its efficacy as a drug highly effective against pneumonia was announced in June 1938. The U.S. patents were eventually granted to May & Baker (1941 and 1942), and it was produced at Bound Brook under license. Ironically this new drug was a setback for Lederle's new and expensive fermentation plant designed to produce pneumonia vaccines.[8] Sulfapyridine made the process almost uneconomic after just eight months of operation (the fermentation would become of some importance during World War II).

Though the sulfonamides were based on the abundant coal-tar intermediates, demand could be met only if sufficient reagents and other chemicals, some extracted from coal tar, were available. This was not always the case, particularly when it came to pyridine. Among the difficulties was the fact that the "sensational sulfapyridine ... was developed when there was a world shortage of pure pyridine." To overcome this problem, a plant for separating pyridine out of coal-tar bases was installed at Bound Brook. Despite the fact that "Sulfapyridine was a short-lived wonder because of its side effect of nausea," it reduced the death rate from pneumonia from 83.1 per 100,000 in the 1930s to 44.1 in 1946.[9]

Other New Jersey firms engaged in early sulfa drug investigations were Merck & Co., Inc., of Rahway, and Maltbie Chemical Co., of Newark. Sharp & Dohme of Baltimore also undertook research into these products. Nine firms in the United States were involved in the patent litigation over May & Baker's second major discovery in 1938, sulfathiazole. It had been independently synthesized by several groups, including at Cyanamid's Stamford laboratories by Dr. Richard O. Roblin Jr. and colleagues. Though no U.S. patent was issued until the mid-1940s, sulfathiazole was manufactured on a large scale in 1940 by Calco, and by Merck. Just as efficacious as sulfapyridine, it had the advantage of being less toxic. Later there were several smaller producers, including Abbott Laboratories, of North Chicago, Illinois. Bound Brook, however, was at the forefront of subsequent American developments, particularly process improvements. At the end of the 1950s it was the world's largest producer of sulfonamides.

American Cyanamid's strong point was a system of interdependent research and development components that focused on Calco's involvement in coal-tar chemistry. Research into pharmaceuticals was generally conducted on two fronts, involving Bound Brook and Stamford or Bound Brook and Lederle. At Bound Brook, Northey and Martin Hultquist were the leading investigators. In 1939, a Chemotherapy Division was set up at Stamford under Dr. W. H. Feinstone, who controlled pharmacological tests. Investigations at Bound Brook were not unlike those carried out in dye research, that is, products with characteristic arrangements of atoms or structural features were prepared and submitted for testing, an approach that was refined once some property of the molecule appeared to offer promise. This meant that chemists steeped in dye chemistry could quickly move over to pharmaceutical research with hardly any change in technique or methodology. Indeed, once specific classes of compounds were modified, by adding or changing atomic groupings, the products were often screened for both biological activity and use in the synthesis of dyes. If novel products appeared to offer potential as drugs and dye intermediates, care was taken to claim for both in patent applications.

The Calco and Stamford laboratories investigated numerous other sulfas. According to Haynes, "Dr. Northey and his team of chemists put together 13 different sulfa compounds. Simultaneously … Roblin and his own team began an independent hunt … Stamford scored on their original synthesis of sulfaguanidine and sulfadiazine," both discovered in 1940. The poorly absorbed sulfaguanidine was introduced in 1941 following clinical studies conducted at Johns Hopkins Medical School.[10] "A strong patent" for sulfadiazine, "a sovereign treatment for pneumonia," enabled Bound Brook to work "an exclusive process." Sulfadiazine (sulfapyrimidine) became important from the end of 1941: "When the war came ... the Army commandeered the supply and wanted more."[11] One reason was that it reduced the high mortality rate—about 35 percent—from meningococcus meningitis (cerebrospinal fever, or spotted fever), a disease that was common among soldiers engaged in active duty. In 1941, Calco came to an agreement with Sharp & Dohme over their patents for sulfadiazine, though after the war this led to a dispute concerning priority and royalties.

Between 1939, the year in which Northey reviewed progress in sulfonamide research before the American Association for the Advancement of Science, and 1947, he and Hultquist, sometimes with coworkers, filed over a dozen patents related to the synthesis of potential chemotherapeutic agents, including alkaloids, following the success of German research into the latter compounds.[12] Lederle, in collaboration with the Research Department at Bound Brook, synthesized other sulfonamides. Sulfaguanadine was followed by succinylsulfathiazole. Years later the *Bound Brook Diamond* announced proudly, if not entirely correctly: "Sulfapyridine, sulfathiazole, and sulfanilamide, the three wonder drugs that have proved so effective against pneumonia and streptococcic infections, are among the pharmaceutical products developed by Calco."[13] Certainly Calco deserved credit for the development of novel processes, if not in every case for the original inventions. Thus novel routes to sulfaguanidine, sulfadiazine, and sulfathiazole were developed from calcium cyanamide.

While drug research was carried out at Stamford, Lederle, and Bound Brook, often in close collaboration with each other and with academic and medical researchers, most of the intermediates for the new drugs, as well as many finished products, were manufactured at Bound Brook. In addition to sulfonamides, Calco continued to manufacture medicinal dyes, which in 1939 included: acriflavine, acriviolet, brilliant green, gentian violet, Hexalet, Mercurochrome, methylene blue, methyl violet, parafuchsin, proflavine, Pyridium, scarlet red, sulfosalicylic acid, and tryparsamide. In 1937, there had been a further extension into pharmaceuticals with the acquisition of the Novocain manufacturer Organic Chemicals Company, of New York.

Bound Brook chemists also played a prominent role in the difficult synthesis of folic acid. This followed the discovery of B group vitamins in the liver during the late 1930s. E. L. Robert Stokstad joined Lederle's Pearl River laboratory in 1941 to work on liver extracts, and two years later he isolated crystals of a *Lactobacillus casei* growth factor from amounts between one and five tons of liver. This was folic acid, a previously well-accepted, but not confirmed, vitamin.[14] It was also known as vitamin "B_C." In 1945, its synthesis was accomplished by sixteen American Cyanamid scientists, eight each from Pearl River and Bound Brook.[15] They had "teamed up to solve this problem ... which baffled the scientific world for six years."[16] The tremendous publicity value was not missed by William Bell when announcing this achievement to the media. Folic acid was manufactured by the Calco Chemical Division at the new American Cyanamid 800-acre Willow Island facility, beside the Ohio River, in West Virginia, opened in 1947. Calco also synthesized various folic acid antagonists. Though folic acid, marketed in various forms, including as Folvite Elixir, never lived up to its promise, other American Cyanamid biological products did, and brought great profits that prepared the way for a major entry into the life sciences.[17]

During 1945–53, American Cyanamid claimed a number of research firsts, several of which arose from Lederle and Bound Brook collaboration. Among the new products arising from this work and manufactured at Bound Brook were: in 1948, Phenosulfazole (Darvisul, the first sulfa drug to affect viruses, synthesized by Robert Parker and Hultquist) and Aminopterin (a folic acid antagonist); in 1949, Hetrazan (diethylcarbamazine citrate, a Calco–Lederle discovery of 1947, for control of filariasis and onchocerciasis in humans and heartworm in animals), Artane (trihexyphenidylhydrochloride, another Calco–Lederle discovery, used for treatment of Parkinson's disease, also known as benzhexol); and, in 1950, *para*-aminosalicylic acid (PAS). In 1949, trihexphenidyl esters of the alkaloid atropine were reported by five Bound Brook scientists.[18]Around 1950, Lederle "produced more than 2,000 pharmaceutical and biological items for human and veterinary use, including sulfa drugs, penicillin, vaccines and serums, and a full line of diagnostics and laboratory agents ... among newer pharmaceuticals and biologicals already in great demand abroad are Folvite folic acid and the sulfonamides, particularly sulfadiazine. Many of these products are manufactured in bulk by Calco," whose direct sales of pharmaceuticals "are limited to manufacturing laboratories located in foreign countries."[19] Except for biological research, including vitamins and experimental therapeutics, which took place at Lederle, pharmaceutical research was now mainly undertaken at Stamford.

American Cyanamid, through Lederle, was deeply involved in antibiotics, which after 1945 tended to eclipse many of the sulfa drugs. Research into penicillin began in the United States during 1941–42, but it took until the end of 1943 before large-scale production by the fermentation process could be achieved. Lederle was at first less impressed with penicillin than Abbott Laboratories, Merck, Chas. Pfizer & Co., Inc., and E. R. Squibb & Sons, perhaps because its faith in fermentation had been disturbed by the impact of sulfa drugs on its new pneumonia vaccine fermentation process.

Wartime work on antibiotics involved the extensive screening of soil samples (the chemical synthesis of penicillin was attempted, but was abandoned in 1945). In 1945, the antibiotic aureomycin, known from 1952 as chlorotetracycline, was isolated by a consultant at Pearl River, Benjamin M. Dugga, a former botany professor at the University of Wisconsin, who was then approaching his mid-70s. He had been engaged by the research director, the brilliant Indian medical researcher Yellapragada Subba Row (who joined Lederle in 1940), to find a safer antibiotic than streptomycin for treatment of tuberculosis. In December 1948, large-scale production was commenced by fermentation.[20] Calco technical expertise was drawn on in certain of these endeavors, notably the important isolation steps. Around 1950, Victor King worked on a phase-separation process involving precipitating, flocculating, chelating, and use of other agents, for antibiotic refining, particularly of aureomycin.

Beetle Urea-Formaldehyde and Melamine-Formaldehyde Resins at Bound Brook

"[A] thoroughly modernized company in the ultramodern industrial field" was the theme of the concluding but never written chapter in Williams Haynes's history of American Cyanamid.[21] Haynes was undoubtedly referring to the corporation's many innovations in highly sophisticated industrial chemistry and successful strategies for diversification, particularly into drugs and the polymeric compounds known as resins. Here, the move into the polymer field is described, using excerpts from Haynes's unpublished history, trade journals, and British versions of events that led American Cyanamid to adopt amino resin technology. It represented a remarkable merger of the technical capabilities in organic chemistry at Calco and inorganic chemistry at American Cyanamid, and established a new use for calcium cyanamide in the production of resins. This followed Cyanamid's close interest in urea-formaldehyde condensation products during the 1920s and 1930s.

American Cyanamid's entry into the polymer field followed an English innovation in the development of urea-formaldehyde resins. At the end of the 1920s, the British Cyanides Company of Oldbury, west of Birmingham, produced novel urea- and thiourea-formaldehyde resins, and from them the first amino plastics. They were known as Beetle aminoplast resins, and their popularity stemmed from the ease with which they could be molded into household and other objects. Rights for their manufacture in the United States were assigned to American Cyanamid in May 1929. The urea-formaldehyde resins were soon modified for use as laminating resins.

Urea was a product that American Cyanamid had manufactured from its calcium cyanamide for DuPont during World War I.[22] At that time, the government backed a major program of expansion in cyanamide production. After the war, this stimulated American Cyanamid to investigate novel processes that provided opportunities for diversification based on its cyanamide. Plastic materials, for which the growing automobile and electrical industries would be large markets, and which offered to be useful in the manufacture of domestic products, were an obvious choice.

In the 1920s the demand was in part satisfied by Bakelite, obtained by the reaction of phenol with formaldehyde, and manufactured by the General Bakelite Company, later Bakelite Corporation. Demand grew so rapidly that Bakelite erected a new factory (replacing facilities at Bloomfield and Perth Amboy, New Jersey, and Chicago) at Bound Brook, some distance east of Calco, during 1929–32 (in 1939 this became a division of Union Carbide & Chemical

Corporation). Bakelite plastics, however, had the one big disadvantage that they were brown or black only, though in the 1930s some colored products did appear, often through the incorporation of Calco pigments; the appearance of Bakelite was considerably enhanced with Calco nigrosine blacks. While this limitation on color may have suited the automobile and electrical industries, it militated against the development of colored household products.

American Cyanamid decided to investigate other resinous products, particularly those based on urea. Like phenol, urea condenses with formaldehyde. This affords methylol derivatives, and then these compounds form polymers.

> With a natural interest in urea since 1924, Cyanamid researchers had been investigating urea-formaldehyde resins but they displayed a disconcerting ability to absorb moisture from the atmosphere with the result that molded articles cracked and warped ... However, in 1928 Dr. N. W. Bauch, the Company's London representative, who was always watching European developments, reported that British Cyanides—later British Industrial Plastics—had overcome these difficulties ... and Bell sent P. B. Watson to England to investigate. Bell and Kenneth M. Chance of British Cyanides worked out an alliance by which the Synthetic Plastics Corporation, a Cyanamid subsidiary, was organized to make these resins in the U.S. under the British trade name Beetle.[23]

The joint company was financed by American Cyanamid, while British Cyanides provided the know-how. In the 1930s, American Cyanamid purchased the British company's interest in Synthetic Plastics Corporation and absorbed that subsidiary. The two firms "maintained close co-operation and assisted each other with technical information to the advantage of both parties."

British Cyanides originally worked with thiourea because this chemical could be made from ammonium thiocyanate, as used in the company's cyanide process. Edmund Charles Rossiter, chief chemist at the firm, condensed thiourea with formaldehyde, and produced an organic glass-like product. The reaction of formaldehyde with thiourea was found to differ considerably from that with urea, and no satisfactory resin was produced, though some "fascinating applications in tiles and laminates showed the possibilities and attracted considerable attention at the British Empire Exhibition at Wembley in

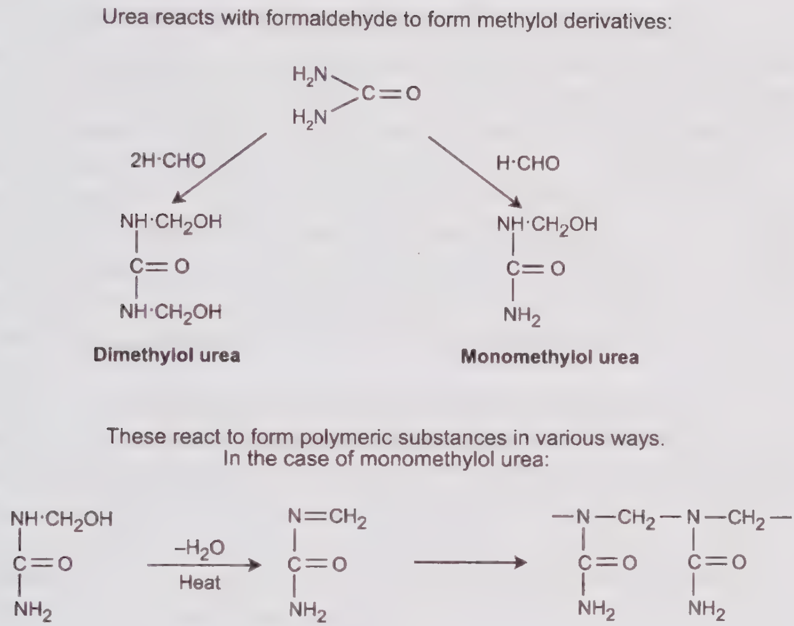
1924." Eventually, in 1925, Rossiter found that a promising material resulted from simultaneous condensation of both urea and thiourea with formaldehyde. The complex resin was used to produce a successful molding powder, in which pigments could be incorporated.

The new product was displayed before the public for the first time in November 1926 at the fashionable Harrods store in Knightsbridge, London, as items of molded tableware for the Christmas season. It was originally marketed as Beatl (beats all), and later as Beetle.[24] After Bakelite, this was the second most important primary development in the field of thermosetting resins. Colored plastics, molded into various shapes, and at moderate prices, were now available for the first time. The urea condensates, unlike Bakelite, had the outstanding advantage that they were "translucent but not *transparent*, and with their commercial success as moulding powders the search for glass-like materials in the urea-formaldehyde field was finally abandoned."[25]

In 1929, shortly after the British Cyanides Beetle process was licensed to American Cyanamid, "American technicians visited Oldbury to see the process, plant was quickly erected at Bound Brook, New Jersey, and production started within the space of a year." Vastly improved molding properties, through incorporation of various fillers, were discovered in the same year by Carleton Ellis, at Montclair, New Jersey. Ellis's patents were the property of Ellis-Foster Co., a firm formed to exploit Ellis's discoveries and in which during 1929 American Cyanamid purchased an interest. Its main asset, Rezyl alkyd resins, became the principal activity of Rezyl Corporation, in which American Cyanamid was also involved.

Initially the Beetle product was based on urea- and thiourea-formaldehyde condensation as in England, but very quickly Bound Brook chemists managed to change the formulation to straight urea-formaldehyde. This reduced the need for thiourea (which was then imported). American Cyanamid created a new subsidiary, linked with Synthetic Plastics, known as Beetleware Corporation to produce tableware and other products from the amino resin.

The international success of Beetle plastics was reflected in the negotiations for licenses between British Cyanides and firms in France, Spain, Holland, Germany, Switzerland, and the United States. There was considerable litigation over patent rights, especially during



Amino resins

Adapted with permission from H. G. Rains, "The Paint Industry as a User of Heavy Organic Chemicals," *Chemistry & Industry*, June 20,1964, 1047–58, on 1051. Copyright 1964 *Chemistry & Industry*.

1933–34. Thus in Germany during 1934, the holders of licenses to the Beetle processes were engaged in a lawsuit with CIBA over the latter's Cibanoid urea-type molding powders. In the same year many of the disputes were resolved, including with Britain's ICI, which in 1933 had purchased an interest in urea-formaldehyde manufacturer Croydon Mouldrite Limited, forerunner of ICI (Plastics) Ltd (1938). An international agreement was reached between British Cyanides and the Pollak Group, Dynamit AG, I.G. Farben, Kuhlmann, CIBA, and ICI for Europe and the British Commonwealth. A second agreement was drawn up with American Cyanamid's Synthetic Plastics in the United States. "When the negotiations were concluded, American Cyanamid also acquired the Pollak-Ripper [Pollopas] rights and Kurt Ripper became their consultant from 1935 until his death in 1942."[26] Independently, in November 1929, Tootal Broadhurst Lee filed a patent for the first synthetic textile finishing resin, a urea-formaldehyde product that made cloth crease resistant.

Laminated sheets made up from urea-formaldehyde resins became available in 1931. In 1933, some 400–500 tons of these new aminoplastics were produced. Appealing to artists and designers alike, the strong, lightweight, colored amino resins made rapid inroads into the production of goods for consumer markets, including molded decorative items such as vases and clock cabinets, produced in a variety of colors.

American Cyanamid was to become synonymous with the next major advance, the production of melamine, and of the polymeric products that bear its name. The triazine compound melamine (2,4,6-triamino-1,3,5-triazine) was first isolated, and named, by Justus Liebig in 1834. The triazine formula was adopted in 1902, following the work of Otto Diels and Frederick D. Chattaway and Lieutenant Colonel John M. Wadmore. Though various industrial reactions for preparing melamine were patented by Henkel and I.G. Farben in Germany and by CIBA, the industrial process was perfected in 1939 by American Cyanamid, which, significantly, employed its calcium cyanamide.

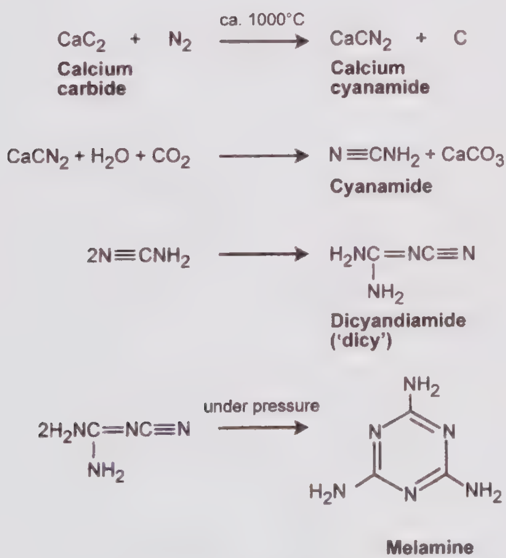
Haynes described the early research at American Cyanamid thus:

> As part of diversification, at Warners in 1933, Palmer Griffith, snooping among odd chemicals made from cyanamide, found that melamine, made from dicyan[di]amide, reacted with formaldehyde to produce a similar product to Beetle, and word came from Europe that the Swiss CIBA was offering a melamine plastic. Melamine was then a rare chemical made here only by Eastman Kodak in laboratory quantities and sold for $40 a pound. At that price Griffith had precious little material to work with, but he did mold three little pin trays and Robert Swain prepared a pound of melamine lacquer.

The results were promising, and a "mass attack was launched to find an economic process" for production of melamine from ammonia and dicyandiamide, also called "dicy." Trials were conducted at the pilot plant of Hooker Electrochemical Company and later at Bound Brook, where Victor King and Carl Mensing collaborated in the research.[27] After over two years of work, in 1939 "[r]are melamine became a commercial commodity; the price dropped from $40 to 40 cents." The profits of the molding compound were soon reaped: "Born in war time, Melmac, Cyanamid's melamine plastic, was at once conscripted—buttons for Army uniforms and unbreakable tableware for the Navy."[28] Progress was such that synthetic resins represented approximately ten percent of total American Cyanamid sales, of around $72 million, in 1940.

From 1941, melamine coating resins were important in the strengthening of paper, again originally for military requirements.

[The] natural resin [rosin] plainly indicated that a synthetic resin that was more efficient might be found ... Because melamine resins seemed likely candidates, this problem was taken up at Stamford ... [Cyanamid's] melamine resins for paper treatment matured in the laboratory just before the outbreak of World War II ... the first commercial production was conscripted for Army uses. Some 40,000 tons was the output of 1943, all used, first for maps, but soon for instruction books and V-mail, shipping tags and multi-wall bags for overseas



Manufacture of melamine

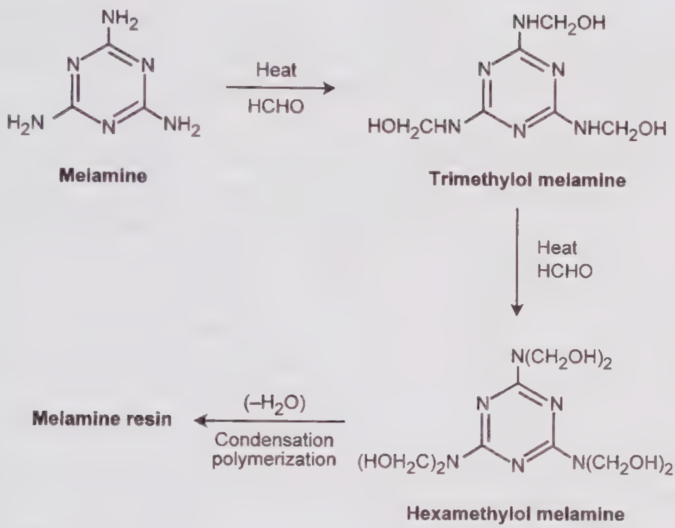
shipment ... When the wartime restrictions were lifted the Mellostrength papers (the trademark that identifies paper treated with Cyanamid's melamine resins) blossomed in a hundred new uses.[29]

Other military uses for high wet-strength papers based on melamine included blueprints and invasion currency. The urea-formaldehyde and melamine resins displayed excellent bonding characteristics and were used in Urac (urea-formaldehyde) and Melurac (melamine-urea-formaldehyde) woodworking adhesives. Until the mid-1940s, American Cyanamid was the only producer of melamine. (DuPont was the only producer of synthetic urea, made from ammonia and carbon dioxide). Since melamine and urea contain highly reactive amido/amino groups, the mode of condensation with formaldehyde was the same. This enabled ready adaptation of processes and equipment used for the production of urea resins to melamine resins, though the melamine reactions were more difficult to handle.[30] While the melamine resins were similar in many respects to urea-formaldehyde condensates, they displayed greater resistance to moisture and heat. The melamine molding product sold under the trade name Melmac represented a tremendous advance in the discovery of aminoplastics, and, because of its superior molding and mixing properties, for many purposes superseded those based on urea.[31]

Haynes pointed out that: "It is easy to say glibly that synthetic materials can be tailor-made to give us more durable, better looking goods, but Beetle and Melmac demonstrate what this really means in our everyday lives. Both are thermosetting resins which are converted by the action of heat or catalysts, or both, into insoluble infusible solids, which are odorless, tasteless, and generally inert chemically. The properties of both can be changed and both are made in solid and liquid forms."

Haynes also discussed the necessity for fillers in molding powders, at first cellulose-filled, but later also fabric- and mineral-filled.

[F]illers result in resins much less sensitive to moisture, but the transparency is lost. However the resulting translucent materials gain a brilliancy and depth of color possible in no other thermosetting plastic, especially in white and pastel shades. The melamine resins, introduced by Cyanamid in 1939, have properties



The synthesis of melamine resin

similar to the ureas, but they are less susceptible to moisture, somewhat harder, and have higher heat resistance. They ... can be modified with alpha-cellulose, chopped cotton fabric, and glass fibers.[32]

In 1940, American Cyanamid erected a new facility at Wallingford, Connecticut, for resin production. It became operational in 1941.[33] Watson developed an improved manufacturing process for urea-formaldehyde resins and was put in charge of the plastics production units at Wallingford and, after the war, at the Willow Island site.[34]

In 1944, total production of urea and melamine resins and molding powders was 126 million lbs., of which 36 million lbs., including fillers, was used in molding. Protective coating applications consumed 6 million lbs.[35] By this time, Calco was producing its Lanaset textile resin, an alkylated melamine-formaldehyde condensate for control of wool shrinkage, the first of many similar products based on the melamine polymer made available by the Textile Resins Department, created in 1945. Among the leading American Cyanamid technical experts in the application of textile resins was Stamford's J(ohn) Edward Lynn (Sc.D., chemical engineering, MIT, 1940), later associated with the *American Dyestuff Reporter.*

From 1945, Melmac was adapted for use in plastic domestic tableware, and became associated with the names of leading industrial designers such as Kate LaMoyne, Raymond Loewy, and Russel Wright. There were two molders of melamine dinnerware in 1946, eleven in 1948, and fourteen in 1950, by which time these products were popular in hotels and restaurants.[36] The domestic market was promoted by American Cyanamid, with, for example, advertisements for "Lovely New Patterns—All Break-Resistant MELMAC Quality!" dishwasher-safe plates in *House & Garden, Ladies' Home Journal*, and *Good Housekeeping*. The dinnerware's popularity declined in the mid-1960s, though new designs continued to appear into the 1970s.[37] Melamine was used in the highly successful laminates in tabletops produced by the Formica Insulation Company, which had previously turned from Bakelite to urea resins. Melamine offered faster curing times, greater durability, and, most important, the use of light colors for hard-wearing countertops in kitchens, bars, dinettes, and drug stores. The Formica decorative laminates for tables and counters would eventually displace linoleum. From the early 1950s, American Cyanamid's molding powders were marketed as Cymel. By then the use of melamine-Fiberglas laminates for electrical panel boards began to face strong competition in the form of glass-silicone composites.

Calco's capabilities in the invention and synthesis of a wide variety of organic chemicals had enabled it during the 1930s to move smoothly into new areas, some based on the same intermediates and types of processes employed in dye manufacture, others on calcium cyanamide. Another early example is American Cyanamid's Laminac polyester resin, introduced in 1943, which, combined with Fiberglas, now called fiberglass, became popular in the manufacture of seamless hulls for small boats and aircraft components. While not typical of American chemical firms, Calco shared with them a common history: "Born in World War I out of necessity, it became one of the founders of the U.S. organic chemicals industry."[38]

Section 2

The Calco Chemical Division of American Cyanamid: 1939–1953

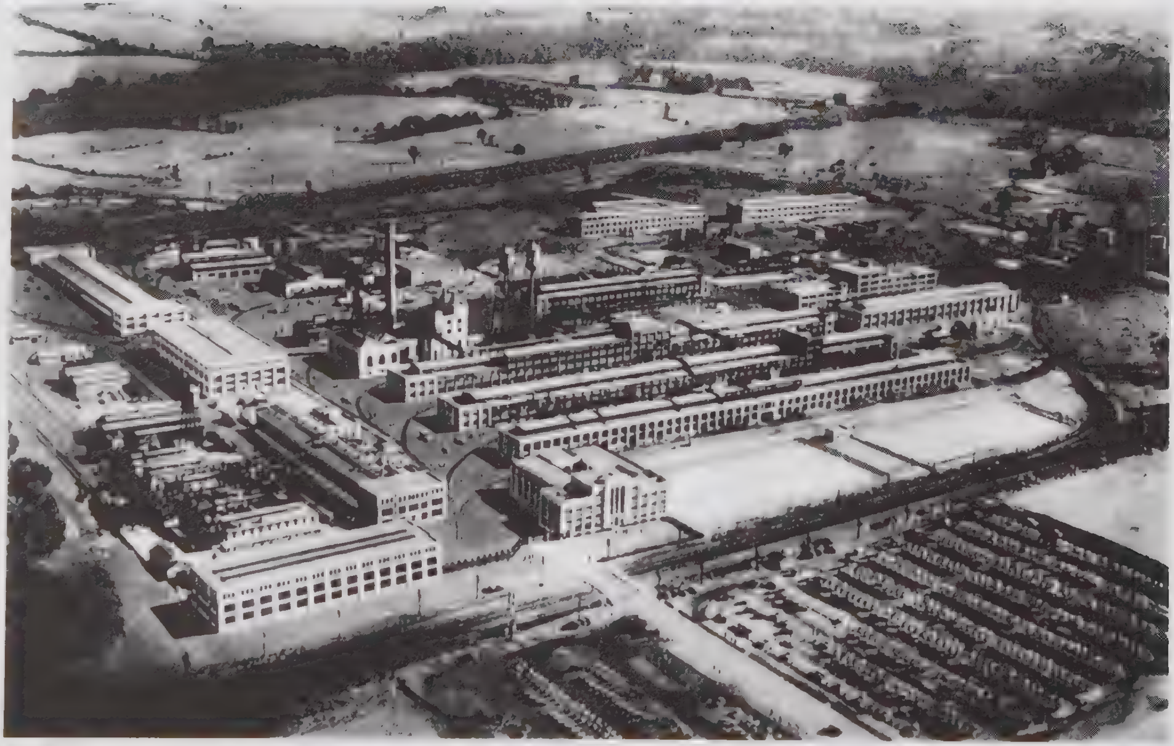
Chapter 4

"And the world knew about Calco"

"The word technical in the dictionaries means 'pertaining to useful arts or to practice, method or procedure.' We have used it at Calco to mean just that as applied to our business, namely, to the 'know how' of manufacturing chemicals so as to make that manufacture useful, that is, to make it make money."—Victor L. King, "The Technical Department," from a talk to Calco student trainees, April 27, 1946. King Papers, MS 429, Dartmouth College Library.

During 1939, the Calco Chemical Company, Inc., a wholly owned subsidiary of American Cyanamid, was merged into the parent company. The Bound Brook facility and its satellites became known as the Calco Chemical Division. It was one of seven operating divisions created by William Bell, the corporation's president. American Cyanamid at that time had three major manufacturing sites, two in New Jersey—Bound Brook and Warners—and a third at Niagara Falls, Ontario. Certain other facilities, such as the Selden unit, were substantial. Research was undertaken at Calco, the General Research Laboratories at Stamford, Connecticut, and the Lederle Laboratories at Pearl River, New York. American Cyanamid had on its payroll 9,800 people, over one-third associated with Calco, including the "Heller & Merz" Department at Newark that specialized in chemicals for the paper industry.[1]

Also in 1939, Jeffcott resigned as president of Calco. John H. McMurray, former works manager and then vice president in charge of engineering and construction, who had recorded the history of Calco's early years, observed that Jeffcott was "a man who shunned publicity, had an abundance of vision, courage and energy as well as great faith." The fact that he refused to be photographed in 1937 for a widely distributed montage of portraits showing Calco managers and



Bird's-eye view of Bound Brook factory, from northeast, 1940. Note extensive parking lot for automobiles in the foreground, buildings nos. 10 (left) and 40 (right), at the entrance to the works, lagoons next to the Central of New Jersey Railroad, and building no. 30 (previously no. 8), which, unlike most later large buildings, points in a north-south direction. (*Dyes Made in America, 1915–1940* [Bound Brook: American Cyanamid Company, 1940]/Edelstein Collection.)

executives is telling of his desire to be kept out of the spotlight.[2] The pragmatic, resilient, and enigmatic Jeffcott certainly had used his connections with and influence among manufacturers, financing from banks, and lobbying for tariffs to pull Calco through several difficulties. After 1929, in Cyanamid's clutches, his commitment to the development of American science-based chemical industry, building on the tradition of dyestuff research, did not ebb. Following Jeffcott's death in 1961, former research director Moses L. Crossley observed of the self-effacing founder: "Even the synthetic fiber industry came to this country largely through his interest and influence with certain banks in New York. He had influence on the permanency of the industry–in other words through the tariff [Smoot–Hawley Tariff Act (1930)] ... The thing to remember is that his name never appeared on any of these occasions."

On May 1, 1939, F. Miller Fargo, former Cott-A-Lap executive, and Calco vice president in charge of sales, was appointed president of Calco in place of Jeffcott.[3] From November 1939 to February 1, 1945, Fargo also served as general manager. The extraordinary material needs of World War II, and the ability of American chemical industry to satisfy those needs, made this the defining period in the history of American Cyanamid's Bound Brook facility. In 1939, as Europe was moving closer to war, national planning in the United States was enhanced with review and overhaul of the existing status of the Industrial Mobilization Plan. On August 9, the Army and Navy Munitions Board announced that President Roosevelt had approved the creation of a civilian advisory committee to be known as the War Resources Board.[4] The latter was to be modeled on Bernard Baruch's World War I War Industries Board. U.S. coal-tar intermediates were high on the list of strategic materials. Production for 1939 reached 605,757,000 lbs., fifty percent more than in 1938, and 30 million lbs. more than in 1937, the previous peak year; 41,775,000 lbs. was represented by aniline oil, 56 percent more than in 1938.

Expansion at Bound Brook

In 1940, Bound Brook celebrated a quarter-century of dye manufacture, as recorded in *Dyes Made in America*, a publication that also served to inform the world that Calco was now a division of the holding company. Thirty-six companies had been merged into what had become the Calco Chemical Division of Bell's highly diversified and consolidated enterprise that since 1928 had spent $15 million on research, as described in the September issue of *Fortune* magazine.[5] Though not all organic chemical production was moved to Bound Brook, the satellite and associated operations, including Lederle Laboratories as well as other chemical manufacturing facilities, relied on intermediates and coal-tar products made there. Business had improved considerably, with earnings per American Cyanamid "B" share rising from 91 cents in 1938 to $2.44 in 1940.

During 1939–40 work began on a pharmaceutical building, no. 101, as part of a new expansion program at the facility.[6] This reflected Bound Brook's rapid progress with sulfonamide drugs, made possible by the special combination of American Cyanamid expertise with coal-tar products, chemotherapy, pharmacology, and animal testing. The growing plastics and resins facilities, to which had recently been added Calco's melamine, employed 300 people. In 1940, a new warehouse with railroad siding access was completed, and work on building 82, for vat and other dye production, commenced. A new power-plant unit was added, a new naphthalene still and a stainless-steel nitric-acid tower were installed, and the liquid-effluent-treatment plant was inaugurated.[7] A 25-ton crane and a third locomotive for serving the extensive rail yards that covered the works arrived.

Though the Calco Chemical Division dominated much of the local economy, and gave extensive employment to residents of the surrounding district, the rapid expansion must have appeared to be a growing threat to the community's amenities. As a public relations exercise, Calco prepared an extensive description of its activities, printed over ten issues of the Plainfield *Courier–News* during April 1941. The articles were reprinted as *What We Do at Calco*. In its pages, Calco personnel described the diversity of their products, how the site collaborated with pharmacological and clinical testing facilities at Lederle, and how civil engineers studied the sources of water, drainage, flood conditions, and the nature of the soil. Bound Brook offered 600 different products, many developed after extensive pilot-plant studies. The Raritan River supplied the newly expanded steam- and electricity-generating power plant alone with 15,000 gallons per minute (gpm), and deep wells provided water at the rate of 1,500 gpm to heat exchangers for process cooling. Automatic control of processes was used in many parts of the facility.[8]

Throughout the United States, the year 1941 was marked by major changes in the relationship between workers and management. President Roosevelt's "Four Freedoms" speech, given on January 6, promised not only support for nations at war with Germany but also, sensing discontent over lowering standards of living at home, a new social contract. There were widespread strikes and labor disputes and, notably, after a mass walkout at the main Ford factory, the United Automobile Workers succeeded in forcing Henry Ford to sign a union contract. For the first time in its history, activities at Calco were brought to a standstill by a work stoppage in 1941. At that time the workers belonged to a local labor group known as Calcocraft, formed following passage of the National Labor Relations Act of 1935 and after workers had rejected the two main national labor organizations, the American Federation of Labor and the Committee for Industrial Organization. (In 1938, Calcocraft was in dispute with the National Labor Relations Board.) The outcome of the strike was that Calco accepted the International Council of Chemical and Allied Industries Union (founded in 1940 through the efforts of the American Federation of Labor) as representing workers, and agreed that on an annual basis the union would engage in collective bargaining on behalf of members. After the formation of the International Chemical Workers Union in September 1944, Calco was represented by Local 111.

Internal politics involving managers of departments, certain strains arising out of social tensions and bristling encounters among individual scientists, were also becoming apparent as Bound Brook grew and diversified. Hans Z. Lecher was appointed associate director of research in 1938, and his promotion is telling about the power struggles. Thus the ambitious research director Moses Crossley was disliked by some colleagues who considered him to be the self-appointed "Mr. Organic Chemistry." Lecher's hiring, and promotion, was in part intended "to show a dagger to Crossley," then associated with both dyes and pharmaceuticals. Lecher was placed in charge of a large dyestuff research section in which he oversaw the work of some thirty to forty chemists. "He had a Prussian manner, though he was not a Prussian, and was renowned at the works for the way he strode through his laboratories without acknowledging the presence of others. He was disliked at Bound Brook because of this. He also appeared to be absent minded ... He had ideas about professionalism that he took seriously ... However, outside of work he was a different person, very sociable, and highly liked."[9] In turn, another outstanding scientist, physical chemist Roy Kienle, became a "rival" of Lecher.

Kienle's early work provides an opportunity to backtrack a little and review noteworthy features of the major endeavor of industrial organic chemistry during the 1930s, the quest for synthetic polymers. His research at the General Electric laboratories, Schenectady, New York, led to the introduction in 1929 of glyptal alkyd resins, made from reacting glycerol with the dibasic phthalic acid, as its anhydride (hence the name *gly*cerol-*ph*th*al*ic). Natural oils, the triglycerides, were also reacted with glycerol to afford monoglycerides that were reacted with dibasic acids to form the polyester alkyd resins. These materials found wide applications in automobile paints, though until investigated further, mainly by Kienle, their macromolecular, or polymeric, natures were not understood.

Around the same time, Wallace Hume Carothers at DuPont began to investigate the mechanism of polymerization and, with colleagues, processes for polyesters, polyamides, and polyvinyls. Carothers identified two key processes, addition and condensation (stepwise growth), that distinguished between the types of polymeric products. This was the context for the furious battles to transform laboratory curiosities into commercial resins, plastics, and artificial fibers. Carothers explained how the Bakelite, alkyd, and amino resins were formed by the process of condensation. However, it was Kienle who from 1930 emphasized the general role of functionality in the design of polymers. He established that alkyd resins were condensation products of polyols, such as glycerol and the newly available petrochemical-derived ethylene glycol, and dibasic acids, such as phthalic acid. In 1929, he published the first of a series of papers dealing with the chemistry of alkyd resins, which led him in 1930 to propose a mechanism for polymerization.[10] Carothers and colleagues at DuPont discovered the synthetic rubber process (for what became Duprene, later Neoprene) in 1929, and this research led to the discovery of nylon in 1935.[11] Introduced in 1938, nylon was the first commercial fully synthetic fiber. Famous for its use in stockings, nylon was an important strategic material, used in items such as parachutes, tents, and ropes.

At Bound Brook, Kienle, with Professor P. A. Van der Meulen of Rutgers University as academic supervisor, and collaborating with Calco chemist P. E. Petke, continued his studies into alkyd resins, for which he was awarded a Ph.D. in physical chemistry in 1938. By that time, production of alkyd resins exceeded the production of phenolic resins, since the greatest demand was for the superior alkyd coating materials. Resins were also playing increasing roles in textile processing, not just for the application of pigments, such as the new phthalocyanines, but also in protection of fabrics. The tremendous international interest in polymers, including technical exchanges and licensing arrangements between major firms covering all potentially useful products that might afford resins and synthetic rubbers, did not escape the attention of American Cyanamid. The main contribution at Bound Brook had been in improving the British Cyanides process for amino resins. It was probably an interest in diversification based on the availability of Selden's phthalic anhydride and Rezyl alkyd resins that encouraged Calco to offer Kienle a post at the Bound Brook Research Department.

In 1936, as a result of contacts with British Cyanides (which in that year changed its name to British Industrial Plastics), Kienle was invited to lecture to the Plastics Group and the London Section of the Society of Chemical Industry at a joint meeting arranged to coincide with an extension of the Paint Research Station, Teddington. Kienle described the structural chemistry of polymers and their films, and "as chairman-elect of the Paint and Varnish Division of the American Chemical Society, the lecturer extended best wishes for the future of the Research Station, and also brought greetings from Mr. W. B. Bell, President of the American Cyanamid Co."[12] Novel alkyd-type resins were produced at Bound Brook from 1942.

Kienle moved increasingly toward applications of instruments to the study of surface phenomena, particularly in dyeing. With George Royer, he applied slow-motion 16-mm color cinematography to the investigation of wool dyeing, as described to the annual meeting of the American Association of Textile Chemists and Colorists in September 1939. This work, and that of Millson, Royer, and M. E.

Wissemann, who made microscopic observations combined with color photography of wool dyeing, appeared in the October 30, 1939, issue of the *American Dyestuff Reporter.* By this time Royer and colleagues were working on applications of spectrophotometry to dyes and dyeing, as described in the next chapter. This work was assisted by the arrival in 1939 of Charles Maresh, who was completing his Ph.D. in chemical microscopy at Pennsylvania State College (awarded in 1940), in 1941 of Harold Russell McCleary (Ph.D. Columbia, 1941), and in 1942 of Charles Loos Zimmerman.

There were other additions to the Research Department staff. William Baptist Hardy joined Bound Brook in 1940, the year in which he obtained his Ph.D. from the University of Chicago. His studies at Calco concerned azo and vat dyes, and later rubber and agricultural chemicals.[13] Arriving at this time was Warren Schumann Forster, from the University of Pennsylvania, where he received his Ph.D. in organic chemistry, also in 1940. Forster's first post was with Neil Mackenzie's group. He worked on explosives, until one of them blew up, causing considerable damage to the laboratory. For a few months he worked at a laboratory in Pennsylvania, where the conditions were better suited to this type of work. After 1945, he specialized in fluorescent and vat dyes. Hardy and Forster spent their entire careers at Bound Brook; later they contributed toward developments in plastics additives and stabilization of ultraviolet (UV) absorbers for plastics and textiles.

Also joining the staff in 1940 was C. Marsden Vanderwaart (B.S., majoring in chemistry and mathematics, Hamilton College, New York, 1936; Ph.D., chemical engineering, Cornell, 1940). He was the first Calco employee to hold a doctorate in chemical engineering.[14] Vanderwaart's reminiscences provide lively impressions of the pace of life at Calco around 1940.

> One summer while at Cornell, I did get a summer job at Calco. I was lab assistant in the Research Dept. working for Dr. E. H. Northey. Martin Hultquist was his able second in command. They were mainly concerned with sulfa drugs. Several times Northey had a beaker full of product, he looked at it sadly and hoped that it would crystallize overnight. It never did. But by the afternoon [of the next day] he would put a nice batch of crystals in the oven. He was a master at the bench ...

One of the other products under development was a contraceptive based on an iodine compound in a starch base. Perfume was added to mask the smell of the starch gel. I had the job to make up the perfumes. One c.c. of the essence into a liter of alcohol. One c.c. of this mixture to a liter of contraceptive. When I went back on the bus that night to Somerville, I was given a wide berth.

In the spring of 1940 I was job hunting and applied to Calco. I was invited down and saw a number of people. Carl Mensing was one. He had little to say to me and I felt intimidated and said even less. It was a very uncomfortable half hour. Dr. Lecher ... asked what I liked to do. I said, "After the chemistry is worked out, I would like to help design the plant." He jumped on the phrase "after the chemistry is worked out." Nevertheless I was hired. It was the only favorable response I received.[15]

Vanderwaart was at first allocated to the Physics Department, in building 41, headed by Robert Park. In October 1940, Ed Groth arrived, and in 1942 another chemical engineer, Hal Bluford Harrison Cooper.[16] "Up to then," in the absence of chemical engineers, "chemists and mechanical engineers cooperated in the technical fields and had done a remarkably fine job. Shortly Ed and I reported to Ken Dixon. We had glass bubble cap distillation columns. Ed had a row of autoclaves."[17] After Dixon was transferred to Stamford in 1941, "we were assigned to Dr. A[lling] Beardsley. He was a gentleman of the first order ... a generation older than us [approaching his mid-'60s]. Nitric acid, distillation and ultramarine blue were his chief interest. I would describe him as a physical chemist, self taught in chemical engineering. We enjoyed working for him." Chief engineer Carl Mensing "was frog-faced, taciturn and extremely competent. I remember the time that he called me into his office, pulled out a sheet of quarter section paper, put a line down the middle and sketched the piece of equipment that would solve our problem. And he was right." Vanderwaart subsequently worked with assistant chief engineer "D[on](arn) H(ard) W(orking) Felch," who along with C. L. Jones "divided the plant between them." Jones later became chief engineer at Bound Brook.

Vanderwaart's early assignments included studies in the melamine shop with John McGreevy. "The melamine operation used a tank car of ammonia a week. There was no chemical consumption. It was all mechanical loss. The shop was not odor free. I got the job to design the larger plant that was built at Willow Island, West Virginia. We made enough improvements so that the plant became a net producer of ammonia." The ammonia was added to the reactor in which the condensation took place to encourage the forward reaction in the manufacture of melamine.

This was followed with transfer to the sulfur dye shop, and then to the Pharmaceutical Department, where on July 1, 1947, he was appointed process engineer. Vanderwaart was particularly struck by the high level of standardization in the mechanical equipment, some of which demonstrated clever applications and improvisations, including Calco's own design of centrifugal pumps. "The differential of a Chevy truck was the standard right angle gear reducer. A V-belt drive gave almost unlimited flexibility. Calco had its own patterns for many cast iron items, including sight glasses and kettles. The same temperature indicator that graced the hood of most cars in the twenties was found all over the plant."[18] During the 1940s, such equipment, and the men, and soon women, in charge of their operation and maintenance would contribute much to the Allied war effort.

World War II: Defense Mobilization

Through his Four Freedoms speech, President Roosevelt prepared the American people for war. In March 1941, he signed the Lend-Lease bill, through which the U.S. government assisted England, Canada, and China with munitions and other essential war materials. America became the "Arsenal of Democracy," with many of its factories, including Calco, now transformed into strategic plants.

Calco was an important cog in the synthetic coal-tar industry of the United States. Plans for national defense found Calco ready to produce many chemicals of vital importance to the war effort. Many of Calco's peacetime products, such as aniline, dimethylaniline, rubber accelerators and anti-oxidants, anthraquinone vat dyes and sulfonamide drugs, found immediate essential wartime use.

By expansion of existing manufacturing facilities, by curtailment of production of materials having only peacetime application, by utilizing equipment and manpower thus made available for the production of war products, and by adapting and rebuilding other existing tools and equipment, Calco was able to increase substantially its capacity for the production of raw materials.[19]

New research chemists joining Calco in 1941 included Robert Henry Ebel (Ph.D., Yale, 1941), and James Fagan Bourland Jr. (B.S., majoring in chemical engineering, Arkansas, 1936; Ph.D., organic chemistry, Purdue, 1941).[20] Bourland was soon engaged in development work on pharmaceuticals. His career at American Cyanamid would take him to Willow Island, New York, and Stamford.

At the same time as the U.S. chemical industry began to prepare for national defense, its trading activities were being closely scrutinized by the Department of Justice. It was widely known that several dye-making and other chemical firms in Europe and North America had reciprocal arrangements over patents and processes, involving exchange of technical information, in addition to commercial agreements over market sharing. From the late 1930s, when big business came increasingly under attack from the Democrats (who were now firmly backed by organized labor), these were often interpreted as instruments of price-fixing and anti-competition. Some undoubtedly were, particularly in the area of dyestuffs and nitrogen products.

For dyestuffs, the activities of the cartel involving Germany's I.G. Farben, Britain's ICI, French manufacturers, and the Swiss firms CIBA, Geigy, and Sandoz were spread over all parts of the globe except the United States. American dye firms, including foreign-owned plants, engaged (more discreetly) in an arrangement that was judged to be in violation of the Sherman Antitrust Act. On May 14, 1941, eight corporations—five American and the three Swiss—and twenty of their officers were indicted by a federal grand jury at Trenton on charges of engaging in an international conspiracy to suppress competition and monopolize the manufacture and supply of dyes. The American firms were American Cyanamid, DuPont, Allied Chemical & Dye, General Aniline & Film (GAF), and General Dyestuffs Corporation. As in certain other antitrust actions, this was in part an attack on the activities of I.G. Farben in America, in this case through GAF and its affiliate, General Dyestuffs.[21] What distinguished this group and the three Swiss firms was that they all manufactured, or traded in, dyes made on American soil. CIBA, Geigy, and Sandoz, members of a "community of interests" created in

1918 in response to the formation of German cartels, jointly owned the Cincinnati Chemical Works, where azo dyes were produced. Fourteen other firms and three more individuals were named in the charges, though they were not indicted.

The day after the Japanese attack at Pearl Harbor on December 7, 1941, the United States entered World War II. American workers pledged that there would be no further labor stoppages in defense-related factories. Patriotism and national defense now became the main factors that drove chemical production. The Office of Emergency Management, the Office of Production Management, and the Supply Priorities and Allocation Board drew up lists of "critical" materials, which included many employed in dye manufacture, such as aniline, phthalic anhydride, and chlorine. They would now find new outlets on front lines.[22]

Aniline oil and its derivative dimethylaniline were already supplied by Calco under contract to the British and Canadian governments. The output of aniline for Lend-Lease shipments had been tripled to an annual rate of around 12 to 15 million lbs. This was now increased to 36 million lbs. following consultation with the Chemical Advisory Committee of the Army and Navy Munitions Board, and then to 48 million lbs. at the demand of the Chemical Warfare Service. The dimethylaniline, or DMA, plant, "whose production capacity had been increased almost 10-fold, was converted to the production of monoethylaniline required for the manufacture of Centralite, a stabilizer in smokeless powder. The greater part of Calco's production of the coal-tar distillate toluene was sold to the Ordnance Department for nitration to TNT."

Bound Brook, American Cyanamid's largest and most diversified facility, became of vital, strategic importance. Its chemists and process engineers were called on to meet new and urgent challenges as part of an epic effort in the cause of national security. Chemicals not previously available were required for newer explosives. Thus, Picatinny Arsenal at Dover, New Jersey, required dinitromethylaniline, DNMA, for tetryl (2,4,6-trinitrophenylmethylnitramine), a booster for TNT. "Picatinny, a development center, had an experimental plant for tetryl using a new DNMA process but had no commercial source. Calco was approached because it made DNCB [dinitrochlorobenzene], from which DNMA is made." Picatinny required highly purified DNCB, which Calco did not have. Kenneth H. Klipstein was involved in negotiations, and was determined to provide a solution. Garrett Hill, development chemist during 1939–44, later recalled that Klipstein "asked me to stop in his office. We discussed the problem, both of us feeling reluctant to admit it couldn't be done here. We talked about various possibilities. 'If we couldn't produce high-grade DNCB, why not find some way to use our crude DNCB?' What happened next made chemical and military history for in two months time the first tank cars of DNMA solution were on their way to grateful Picatinny officers. Calco management then had the task of assuring area communities that contrary to rumors of alarm, the plant was not making an explosive."[23]

Production of benzene, toluene, xylenes, phenols (including cresols), naphthalene derivatives, and *para*-aminophenol, as well as resins and sulfonamides, were expanded greatly. American Cyanamid began the manufacture of thiourea in 1940; previously the corporation was the main importer and distributor of this chemical, required for organic sulfur compounds. Cyanamid's melamine production increased from 352,296 lbs. in 1940 to 6,922,705 lbs. in 1944. Melamine found use in coatings and laminates, plastics, and glues, including "Army map and chart paper, naval electrical panels, aircraft ignition parts of great arc resistance, tableware for the armed forces, adhesives for plywood planes and wet strength paper." During 1942, total U.S. dye production reached 152 million lbs., and coal-tar intermediates 1,230 million lbs., the latter figure reflecting the tremendous growth in demand for aromatic compounds used in products other than dyes, including rubber-processing chemicals and synthetic resins. In December of that year, Calco's Roy A. Shive was transferred to the government's Rubber Reserve Company in Washington to assist in the development of chemicals for synthetic-rubber production. Arnold Rogers Davis, who specialized in rubber chemicals, accelerators, and antioxidants, spent two years (1943–45) with the government's Office of the Rubber Director and its successor, where he participated in the wartime synthetic-rubber program. Until 1953, Davis was head of the Bound Brook Rubber Chemistry Laboratory. During 1953–57, he managed the Stamford Rubber Chemicals Section, after which he returned to the Bound Brook laboratories, and then served the Organic Chemicals Division.

Over half of all the beta-naphthol demanded by the rubber industry was supplied by Calco. It was converted into phenylbeta-naphthylamine, the most widely used antioxidant. Other essential rubber chemicals were made from paraphenylenediamine, aniline oil, and *para*-amino phenol. In addition, there were "additives for aviation gasoline to increase the octane rating, and in lubricating oil to inhibit gum formation and give the oils longer life under extreme operating conditions, in tanks, planes and other military vehicles."[24] Calco manufactured the mercaptobenzothiazole accelerators for use in the processing of synthetic tire rubber at the request of the Office of the Rubber Director and the War Production Board.[25] Though not produced at Bound Brook, acrylonitrile was another new American Cyanamid product, initially also required for wartime synthetic-rubber production. It was first made in the United States at Warners in 1940.[26] In 1942, a pilot plant was set up at Bound Brook for unsaturated alkyd resin polymers, obtained through condensation of maleic anhydride with ethylene glycol, with subsequent styrene cross-linking. This thermosetting vinyl polyester copolymer, used in low-pressure laminating, was given the trade name Laminac.

Water- and weather-resistant Urac and Melurac liquid-resin adhesives bonded the plywood used in the construction of aircraft such as the Curtiss C-76 caravan transport plane and the AT-13 bomber crew trainer. They held together the hulls of high-speed PT (patrol torpedo, or motor torpedo) boats. The bacteria-resistant melamine adhesive was widely used in other marine applications. Calco's cold-setting Beetle-based cement facilitated the production of the wooden mosquito bomber.[27]

Dyes and pigments that were used in peacetime as eye-catching decoration were now required for concealment. Billions of yards of fabrics had to be dyed and receive special treatment, including for camouflage and uniforms. The military requirements for Calco's textile colorants were largely for the vat dyes used on cotton that resisted fading when exposed to light and washing (unlike the sulfur dyes used in World War I). The "browns, olives, and khaki were restricted by the War Production Board solely to the dyeing of textiles. For two of these colors Calco was building a plant at the start of the war, for slightly over 200,000 pounds per year. This production was increased to 1,000,000 pounds per year by conversion of equipment normally used for blues, greens, etc., ordinarily sold to the civilian market." During the war years there was less emphasis on wool dyes, though they were required for uniforms.

Calco manufactured intermediates for vat dyes for its own use, and sold some under allocation to other producers of these important colorants. This brought profits, but held back new innovations. "Calco's extensive program of developing vat dyes by the purchases of processes from other plants here and abroad in the 1930s and by the development of our own processes for the manufacture of certain vat dyes, was progressing satisfactorily by the beginning of the war, and, of course, had to be interrupted in order that war needs could be supplied first. This set Calco's program for getting into the vat dye market back by at least seven years."[28] The setback was later made up through imitation of German processes and investigations into the constitutions of rival DuPont products.

Other contributions to the war effort included colorants for fluorescent signal panels, signal smokes, and sea markers. The latter, developed at the Anacostia Naval Research Laboratory in Washington, D.C., during 1942–43, were based on the Calco-made dye uranine (the sodium salt of fluorescein), which before the war was produced at the annual rate of 2,000 lbs., mainly for use as a sewage tracer. From 1943, uranine was produced at an "annual rate of 450,000 lbs. ... for life jacket dye packs used to locate Navy and Army personnel shot down over water."[29] This marker produced a large yellow fluorescent patch on sea water for up to three hours that was visible ten miles away at a height of 10,000 ft. It was highly effective, helping, for example, to save downed aircrew from Admiral Mitchner's task force off the Philippines in June 1943.

Uranine was also used for depth-charge markers "and other devices for tactical marking of the ocean."[30] During 1943, large shipments of colored smokes were supplied to the Chemical Warfare Service, following collaboration between Calco technicians and Edgewood Arsenal, Maryland, where Wendell Munro was based during 1942–45. Calco scientists worked with the Engineers Corps at Fort Belvoir, Virginia, in the development of a resin-pigment combination. This was used "for shrimp net camouflage for mobile equipment and for burlap strips used in netting camouflage for gun emplacements. In December 1943, a production in excess of 750,000 lbs. of this material was obtained in equipment normally used for the production of materials diverted from other operations."[31]

In March 1942, Harold J. Coolidge at the Office of Strategic Services began the search for a shark chaser, or repellent. Investigations soon became based on Calco's nigrosine range and induline, mixed with copper salts, particularly copper acetate, whose taste and smell were not liked by sharks. The copper acetate, however, caused precipitation of dye and loss of color. A special nigrosine colorant named Calco WBSR was tested during 1943. In 1944, the Naval Research Laboratory asked Calco to undertake further investigations, and Harold T. Lacey, working partly at the naval laboratory, developed a soluble nigrosine-based polyp "ink" similar to the protective liquid emitted by sharks.[32] The marker and shark-repellent containers became part of the standard equipment in lifeboat, life-raft, and life-jacket survival kits (known as the Life Jacket Shark Repellent Compound Packet). However, the shark repellent was less effective.[33]

American Cyanamid's achievements were such that the State Department and the Office of the Coordinator of Inter-American Affairs both supported moves to enable the corporation's takeover of I.G. Farben facilities in Mexico that had been sequestered by the Mexican Alien Property Custodian.[34]

The sulfonamides sulfadiazine and sulfaguanidine were supplied in bulk to the Army and Navy Munitions Board. In 1942, sales of these coal-tar pharmaceuticals increased 60 percent in value and 29 percent in quantity, the largest increase for any special group of chemicals. During the following year, Calco produced around 97 percent of the U.S. consumption of sulfadiazine, and was the sole American producer of sulfaguanadine. "As a result of Calco's position on those two products and their requirement by the armed forces, Calco was directed by the Army and Navy Munitions Board to produce them to the exclusion, if necessary, of all other sulfonamides."[35] By 1943, sulfathiazole had became the drug of choice among the armed forces; it cured common diseases caused by streptococcus, staphylococcus, pneumonococcus and gonococcus, as well as preventing and curing wounds and burns. Considerable ingenuity was displayed at Calco in developing manufacturing processes under the imperative of wartime needs.

The scale of production of these and similar fine chemicals was enormous. Vanderwaart recorded: "We made half a dozen different sulfa drugs totaling several hundred thousands of pounds a month … I often ratioed … a 4-oz. bottle of sulfadiazine … up to the hundreds of thousands of pounds that we were shipping to the military. It was for this assignment that I was deferred and I have never had any military experience." Mensing, Harvey Whitten, Jim Needles, and Ed Soriano played prominent roles in maintaining sulfa-drug production, which brought its own unique challenges, particularly an adequate and continuous supply of pyridine, not just for sulfapyridine, but also as a solvent. This was made possible by efficient recovery from the manufacturing processes:

> Each of the sulfa drugs was made in a non-aqueous reaction. Pyridine was the solvent of choice. The usage of pyridine was so high that a recovery operation was called for. Ed and I did experimental work on benzene extraction and distillation. Pyridine and water form an azeotrope and so pure pyridine cannot be recovered by distillation alone. Mensing designed the multistage, countercurrent, series of extractors that required no between stage pumps. The Mensing extractor earned a well-deserved place in the chemical industry.[36]

New and replacement equipment made necessary by the sudden increases in demand sometimes created unexpected problems. Some were minor, but annoying and time-consuming. "The naphthalene hydraulic presses in the BN [beta-naphthol] shop had been made in Germany. When they had to be replaced during the war, Ed Soriano was given the job to convert the metric drawing to American units."[37]

It was with considerable self-satisfaction that American Cyanamid could later review the contributions of its Calco Chemical Division: "As a war plant, Calco underwent a vast change. There was a great turnover of employees as the armed forces grew in size. Production was altered and speeded up, bond rallies were held, plant protection tightened, and the first casualty lists of employees came in. Radio station WMCA carried a tribute to Calco on its popular 'Bright Breidt Show' and Dr. M. L. Crossley, research director, was interviewed by Fulton Lewis Jr., radio commentator, on Calco's sulfa. And the world knew about Calco."[38]

Excellence on the war-production front was officially acknowledged by awards of pennants to individual factories, rather than to companies. In 1941, the navy awarded "E" pennants and the army "A" pennants. In 1942, they were consolidated into Army–Navy E Awards. Receiving plants proudly flew the pennant, on which was printed a large capital letter E, and workers at every plant where the award was given received a lapel pin. ("M" pennants were awarded to shipyards).

Divisions (later Departments) at Bound Brook in 1943

Division A	Intermediates, including beta-naphthol, sydite, dimethylaniline, nitrobenzene
Division E	Azo dyes
Division F	Alkali blue, malachite green, methylene blue, methyl violet, etc., including the ink and lake shops
Division G	Vat dyes
Division H	Melamine, nigrosines, sulfur colorants, stilbene, auramine, Tobias acid, etc.
Division I	Inorganic acids
Division M	Maintenance, construction, and services, including carpenters, electricians, machinists, millwrights, masons, painters, pipefitters, gauges and pumps, and the Instrument Department
Division N	Light-oil and tar-acid distillation
Division P	Pharmaceuticals, mainly sulfonamides
Division R	Rubber products: MBT, thiourea
Division U	Bagging
Division CS&B [Color Standardization and Blending]	Blenders, mills
Division W	This covered stores, and the railroad and road operations within the facility

Divisions U and W later became Department U&W.

The first Army–Navy E Awards were handed out in August 1942, and by the end of the war had been presented to 4,238 factories. In 1942, four American Cyanamid sites received E awards. On January 20, 1943, it was Calco Bound Brook's turn to be handed its E award. For the presentation rally, 3,000 staff members gathered in building 35, where Brigadier General Alden H. Waitt, Chemical Warfare Service, Army of the United States, and Commander Herman J. McCarthy, U.S. Navy, made the presentations.[39] Following acceptance of the pennant by Fargo and Frank C. Pucci, president, "Chemical Workers Union Local," the staff were entertained by singer-actor Paul Robeson. The ceremony, also attended by Cyanamid president William B. Bell, was transmitted over the Radio Blue network. Bound Brook later added four stars to its E pennant.[40] By the end of the war, twelve American Cyanamid facilities had received E awards.

To handle the increased output, the Van Horne House, almost opposite the factory entrance (on a perch at the south of the Hill Property), which Calco had purchased in 1937 and restored, provided wartime sales-office quarters. At the end of 1943, Robert Collyer was appointed advertising manager of Calco, and Morton Starr Cressy Jr., previously head of aniline, rubber accelerators, and beta-naphthol, became sales representative for chemicals and intermediates.

During the war years, there was tremendous demand for, and growth in, production of Calco's pigments. This was assisted by a further acquisition, late in 1943, of Interchemical Corporation's United Color & Pigment Company Division, at Newark, that produced organic and inorganic pigments. United Color employed 500 people, including Clifford D. Siverd, who was to become president of American Cyanamid in 1967. What now became Calco's United Color and Pigment Division was soon merged into the Calco pigment-making sections. United Color's organic pigments were manufactured at Bound Brook, in the then new building 86. In 1944, Interchemical's unit at Piney River, Virginia (Virginia Chemical Corporation), that manufactured titanium dioxide pigments, also became part of the Calco Chemical Division.[41] In January 1944, Calco's Harold Lacey, who had undertaken research into pigments and oil colors, was appointed division chemist in charge of lakes and intermediates for the dry-color and printing trade. In May, Sam Klein, who since 1924 had been in charge of lake pigments at Calco, became western sales manager, operating out of the Chicago office, where he joined Frederick H. Heiss, former Bound Brook chemist who undertook sales and service for the paint and printing ink trades, and other users of pigments.

The navy required ultramarine for paints and other pigments for the coloring of tarpaulins. During the war years, forty-four Calco Technical Bulletins dealing with recipes and processes for U.S. armed

Interesting Shots from Here and There

Calco Receives "E"

On January 20, workers and management of the Calco Chemical Division, American Cyanamid Company at Bound Brook received the Army-Navy "E" Award for excellence in war production from General Alden H. Waitt, Chemical Warfare Service, Army of United States, and insignia pins for every employee from Commander Herman J. McCarthy, United States Navy, in a colorful ceremony.

The presentation, which was held in one of the plant buildings, featured fighting speeches by General Waitt and Commander McCarthy and a gracious address of acceptance by F. M. Fargo, Jr., General Manager, and Frank J. Pucci, President of the Chemical Workers Union Local.

Left to right, F. M. Fargo, Jr., General Manager at Calco; General Alden H. Waitt; Commander Herman J. McCarthy, and Frank J. Pucci.

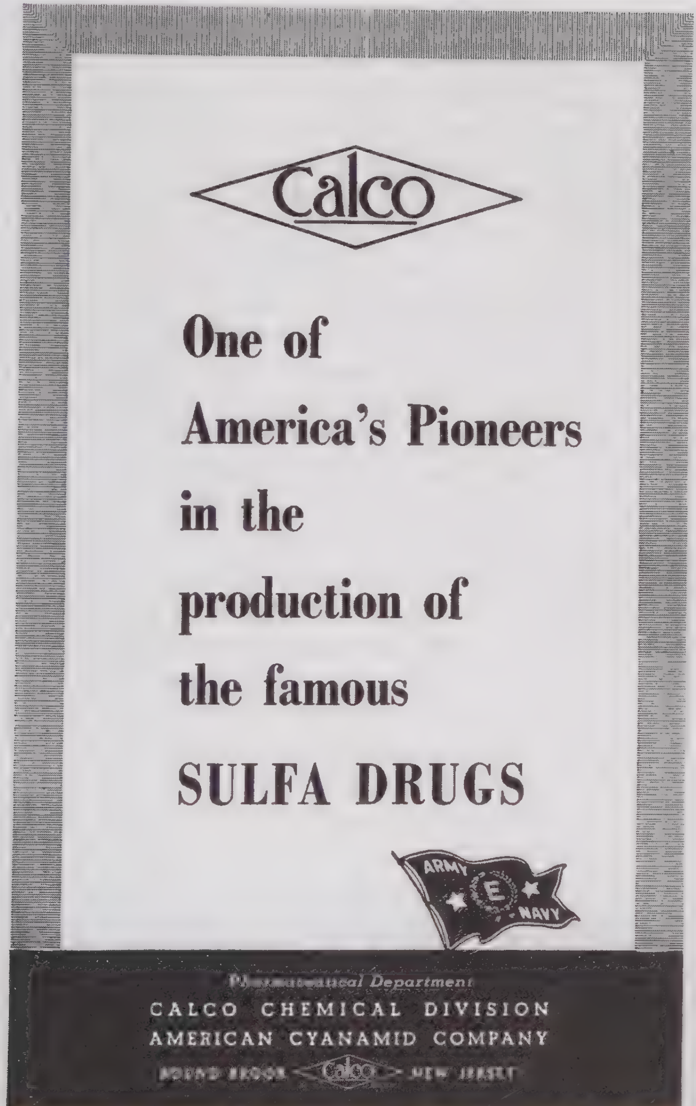
Presentation of the Army–Navy E Award for excellence in war production to the Calco Chemical Division, January 20, 1943. (*Chemical Industries* 52 [February 1943]: 222.)

services supplies were produced, many to instruct dye and pigment users in how to meet Army Quartermaster Corps and federal specifications. This included vat dyeing of cotton, dyeing of sandbags, denim, uniform twill, nurses' uniforms, wool for army and marine uniforms, mosquito and camouflage netting, cotton duck for shelter tents, blackout draperies, and leather goods, and coloring of plastics.

Research received greater recognition with the creation of the post of research associate in January 1944. This encouraged outstanding scientists to stay at the bench, without being burdened by administrative duties, but still enjoying the prestige of colleagues on the management ladder. It was not until early 1946 that DuPont created the post of research associate, of which there were three grades.

"Good Morning, Have You Been Indicted?"

In rallying to the defense of the country and fulfilling military contracts, Bound Brook demonstrated the highest level of patriotism at a time of great crisis. Several Calco scientists and technical people were



Advertisement for Calco sulfa drugs, showing Army–Navy E pennant, with two stars. (From "Special Issue, 108th Meeting American Chemical Society, North Jersey Section, September 11 to 15, 1944. Silver Jubilee, New Jersey Chemical Society," *The Indicator* 25, no. 7 [September 1944]: 31. Reproduced with permission of the North Jersey Section, American Chemical Society.)

co-opted as civilian advisers to major government bodies. In addition to those already mentioned, they included: Kienle, who served with the Office of Scientific Research and Development; Crossley, consultant to the United States Army; and King, who undertook a two-year stint with the Department of Commerce. Vanderwaart remembers that Robert Park "spent most of his time in Washington on submarine work of some kind." Park was in fact engaged in developments at the Naval Ordnance Laboratory during 1941–43.

One group of federal employees, those at the Department of Justice, had a very different agenda. Their job it was to keep a close eye on potential and likely antitrust violations and profiteering in pharmaceuticals, explosives, drugs, and other sectors. Manufacturers were frustrated, and sometimes stunned, by the department's incessant and often hostile demands for transparency, particularly in prewar dealings with I.G. Farben. The mood of the industry was reflected by an editorial in *Industrial and Engineering Chemistry* under the heading "Good Morning, Have You Been Indicted?"[42] While assertions of wrongdoing were couched in general terms, some were substantiated, at least according to the prevailing criteria. Thus excess profit taxes of $453,461 were imposed on American Cyanamid for the illegal activities of its Calco Chemical Division following the May 1941 judgment. This amounted to about 8 percent of the corporation's net income of $5,666,901.[43] It must have been difficult for the Quaker William Bell to inform stockholders in the 1942 annual report of the misdemeanors carried out at so important a strategic manufacturing division.[44] It was certainly less difficult to record that "as was expected, varied problems were faced during 1942. Personnel shortages, increasingly acute, have been overcome with some degree of success by the employment and training of women and by longer hours of work. The ingenuity of operating and technical staffs in adapting new processes and substitute materials to existing facilities and expanding programs has achieved production rates otherwise impossible."[45]

"Speed the Victory–Plan for Peace" was the slogan of the American Chemical Society's 108th annual meeting held in September 1944. Honorary chairman of the meeting was Calco's August Merz, long-serving president of the Synthetic Organic Chemicals Manufacturers' Association. The events were held in New York and the meeting was hosted by the North Jersey Section. With wartime considerations in mind, participants were advised that "only serious technical discussions are in order. If anyone is only interested in the social aspect, he should stay home." Bound Brook's Crossley, aided by Northey, Lecher, and other colleagues, did, however, find time to welcome guests with beer and Coca-Cola at a reception held at the Hotel Pennsylvania.[46] At one session, American Cyanamid's Lois Woodford led a discussion on "Postwar Plans for Women Chemists."

By this time, several women chemists had entered the Bound Brook laboratories to participate in routine work, as well as, occasionally, analytical and research projects, particularly spectroscopy and organic synthesis. Among the latter, William (Bill) Hardy remembers: Ruth Abbot, M.S., who worked in the Physical Chemical Group as a spectroscopist from 1941 to 1950; Barbara Roth, Ph.D., synthesis chemist from 1941 to 1951, when she resigned to work as a group leader at the Toni Division of Gillette; Corris M. Hofmann, Ph.D., organic chemist, from 1941; Elizabeth M. Hardy, Ph.D., organic chemist, from 1942 (she worked with Bill Hardy, though they were not related); Donna B. Cosulich, Ph.D., organic chemist, from 1943; and Doris Seeger, Ph.D., research chemist in pharmaceuticals, from 1943. Anna M. Harding was another Bound Brook spectroscopist engaged in research during the 1940s. Cosulich and Seeger were members of the Bound Brook team that synthesized folic acid. In the mid-1950s, Cosulich, Hardy, Hofmann, and Seeger were transferred to Pearl River. In 1968, Seeger joined the Office of Government Controls as assistant director of the Medical Control Branch.

Perhaps it is fitting that the two remaining indications that there was once a bustling factory at Bound Brook are connected with the sacrifices and sufferings demanded by war, both at the battlefront and on the shop floor: a memorial plaque unveiled in May 1947, dedicated to 67 employees of the Calco Chemical Division who died in the service of their country; and the underpass, constructed in 1941–42 following a spate of accidents occasioned by the greatly increased staff and rail traffic, that replaced the railroad level crossing at the entrance to the erstwhile works. The names on the plaque reflect many social and cultural backgrounds, including second-generation Italian and East European immigrants whose families came to Bound Brook and the district in the early 1900s originally to work in the then-flourishing woolen mills (Manville, for example, had a large Polish population).

Lowering Social Barriers

During the war, 2,000 Calco employees left for military service. The resulting staff shortages and demands on production schedules forced the management to find alternative, as well as additional, sources of labor. Calco was anxious for help from any quarter. The outcome was a change in the social composition of Bound Brook. Jobs previously closed to women and minorities, even if temporary, were now readily available. Before the early 1940s, a few women chemists had been employed in the laboratories and the library, and other female staff served in the medical division. Now they were joined by over 400 women who came to replace men in the plant, mainly on the shop floor. The total workforce grew to nearly 5,000, including groups of coal miners from Pennsylvania, and Spanish-American, mainly Puerto Rican, and black laborers, men and women.

Despite President Roosevelt's 1943 executive order to create the Committee on Fair Employment in order to remove discrimination, the reality of acceptance was often very different. Neighbors of the plant protested at the end of the year when they discovered that barracks were under construction as living quarters for "colored people." American Cyanamid nearly became embroiled in a court action in its efforts to bring these workers to Bound Brook. On December 30, 1943, at a meeting of the Bridgewater Township Committee, "Counsel Allgair stated that the Township Committee could not keep the colored people from living there as it would be violating the Constitution of the United States and he did not think a Court would prohibit them from living there as the Country is at war and the Calco Chemical Company no doubt needs the men in the Plant to produce the vital war material."[47]

Before the war it would have been almost impossible for Jewish chemists to aspire to research and most other responsible positions at large American firms, but at Bound Brook, if not elsewhere at American Cyanamid, that had all changed.[48] Among these newcomers in the research laboratories was, in 1944, Jay Leavitt, who had studied for his Ph.D. at Harvard under the English phthalocyanine expert Reginald P. Linstead. After Linstead returned permanently to England in 1942, Leavitt moved to the University of Pennsylvania, where for two years he undertook research into explosives. He applied for a post at Bound Brook, and was interviewed by Lecher, who, greatly impressed by the Linstead connection, offered Leavitt a position in dye research.[49] Leavitt was a close colleague of Isaiah Von and Erwin Klingsberg (both also Jewish), who joined Bound Brook in 1946.[50]

Jewish chemists fared reasonably well at Bound Brook, possibly because, as Jay Leavitt recalls, "some of the small dye manufacturers acquired by Calco were owned by Jewish entrepreneurs in Northern New Jersey. A number of them came along with the processes and equipment. Prominent among them was Lou[is] Robins who played a significant role in vat dye manufacture." Robins was plant manager at Bound Brook during 1952–53, after which he was appointed manager of manufacturing for American Cyanamid's newly created Pigments Division.[51] Leavitt observed: "I think his company brought along the process for the thioindigoid Vat Pink FF, which as I recall had nine isolated intermediates and was probably the most difficult vat dye to make."

On February 1, 1945, Sidney Moody was appointed general manager of Calco, though he had been acting in that capacity since August 1943. Product diversification at Bound Brook, often based on dye intermediates, had led to extensive reorganization, particularly the establishment of various technical committees that in the early 1940s oversaw the eight manufacturing departments (then often referred to as divisions). A ninth, Textile Resins, was created in 1945. Each manufacturing department had its own chief chemist. Victor King, who personified the new breed of professional technologist-manager, described the organizational structures thus:

> The center of technical activity at Calco lies in the group of Technical Committees. There are nine such committees and in them is lodged the responsibility and the authority for all manufacturing processes. The manufacturing plants are divided into nine corresponding divisions, each of them functions through its own Technical Committee. The membership of these committees is made up of the chief chemist of the Division, the chief

engineer of the Division and the operating manager of the Division, with a common chairman of all the committees–the Manager of Control and Development. In that way each of the three important functions of chemist, engineer and operator is intimately incorporated into one body of responsibility and authority.[52]

Less formal were the special interest groups at Bound Brook, such as the Chief Chemists' Club, where overviews of recent developments in fields of interest to the factory were reviewed by staff members.

The Spoils of War

At the 1952 inaugural meeting of the industrial group of the American Association for the Advancement of Science, American Cyanamid's chemical director in New York, Norman A. Shepard, advised his audience that "today America occupies the position formerly held by Germany as leader in this [dyestuffs] industry."[53] Certainly America had come a long way in the manufacture of organic chemicals since 1915, and could point to its own achievements, some, such as the widespread use of instrumentation in research, dye standardization, and quality control, and diversification based on dye intermediates, the outcomes of Bound Brook innovations. Part of the early success had derived from the availability of German processes after World War I. During 1946–48 there was a similar distribution of German industrial knowledge among American manufacturers, who were now much better able to appreciate the more immediate implications. This is one reason why by the early 1950s, often exploiting newer German discoveries and inventions to great advantage, the United States had become the largest manufacturer of synthetic dyestuffs.[54]

The onset of the final months of war in Europe was the signal for teams of Allied investigators to seek out the secrets of German science and technology. The Allied nations established commissions of inquiry whose assignments were to gather information on German developments that could be exploited for both military and civilian uses. Organic chemistry featured highly in their endeavors, particularly the manufacturing processes and products of I.G. Farben, which during the decade leading up to 1945 had introduced novel plastics, resins, and adhesives. After its conquest, Germany was divided into four zones, one controlled in the east by the Soviet Union, and three in the west by France (central zone, Upper Rhine, including BASF), Britain (northern zone, Lower Rhine, including Bayer), and the United States (southern zone, Main, including Hoechst). Just over half of the chemical industry's productive capacity lay in the Soviet zone. On October 12, 1945, the coordinating committee of the Allied Control Commission decided to confiscate I.G. Farben's assets and dismantle and distribute as reparations parts of around 300 factories. Pharmaceutical facilities only were to be retained.

The main war booty, however, was information on new processes and products. As Herbert Levinstein in England explained, "the main strength of the I.G. lies not in their factories. To destroy an enemy's factories often proves in the long run to his advantage. He re-builds them better. It is the human element, the team, the accumulated knowledge that counts."[55] Gathering the accumulated knowledge of I.G. Farben meant, as a first step, dealing with the occupying authorities in each zone. This was not always straightforward, as an American Cyanamid team soon discovered.

In July 1946 the corporation sent at its own expense four technical experts, two from Calco, to Europe as a contribution toward the investigative work of the United States Field Intelligence Agency, Technical (FIAT). Their brief was to prepare a number of reports for the Office of Technical Services, Department of Commerce. One incentive was provided by the fact that when the U.S. government stopped funding technical trips in January 1946, it invited firms to send suitably qualified scientists for extended stints (three months was suggested) as representatives of the government, as well as in their own interests. Over 200 civilian scientific consultants were sent by their employers on these trips. Seventy were members of the Chemical Unit, Technical Industrial Intelligence Branch of the Joint Intelligence Objectives Agency, based in Washington and headed by Julius Alsberg. Another incentive, perhaps, was the fact that in July the London Agreement enabled all German patents sequestered by August 1 to be made available to the civil economy as from November 30.

To help assess in advance the potential of German patent and other information, American Cyanamid must have figured that on-site examination of plant and interviews of personnel would be invaluable. In addition, the American Cyanamid team probably went to Germany in an effort to prevent DuPont and GAF (then in the hands of the U.S. government), whose technical people were interested in intermediates and dyes, from gaining the upper hand in the acquisition of knowledge about developments in German industrial organic chemistry.[56] The representatives of Calco were Victor King, head of the team, and his assistant from early 1946, Dr. Robert P. Parker, previously group leader in the Research Department.

Late in 1946, King described the European visit to a group of Calco chemists. His manuscript is a unique personal account that fully captures the awe in which I.G. Farben technology was still held, despite years of isolation from the international community and the difficult conditions in German industry. King and colleagues

> visited the chemical industry in the British, French and American zones of occupation in the enemy country of Germany. This … visit was made for the Department of Commerce and under the auspices of the American Army of Occupation. For this reason we are not permitted at this time to release any details concerning the chemical industry in the enemy country until the seven reports we made to the Department of Commerce have been released to the public. The object of this is to prevent our company enjoying any advantage because of the fact that it sent four men on this mission and paid all their expenses. So my remarks at this time about the German chemical industry will have to be general in nature.

Noteworthy is the following section, which describes the tremendous competition for the secrets of German processes, not so much among the Allies, but mainly among the American personnel.

> Mr. Fromholz, Dr. [Jack Theo] Thurston [director, Chemical Research Division, Stamford], Dr. R. P. Parker and I left this country last July and went directly to Germany in order to do the chore of the Department of Commerce first, so that two of us could then visit the chemical industries in the countries of our allies as soon as possible. We encountered a somewhat surprising attitude on the part of some of the American officials in charge of the Chemicals Branch of the F.I.A.T. which stands for Field Intelligence Agency, Technical. They gave the impression that everything we were

interested in had already been investigated especially dye intermediates and they were concerned lest the Germans be disturbed too much by too many investigators. The Germans were so busy producing chemicals that to waste time with American investigators, especially men from the American chemical industry, would be highly undesirable. The American officials seemed surprised that the American Cyanamid Company would send a group of four men all at once and seemed afraid lest our company get some special advantage of that. This attitude weakened in time, but, as we gradually learned later on, was based in part upon the desire of some of these consultants to go home themselves as individuals with a suitcase full of German processes and peddle them out, especially to the smaller companies in America. One consulting engineer tried to acquire 900 drawings from Oppau [the BASF synthetic nitrogen factory] for this purpose and another collected about 2,000 "processes" which he frankly told any and all who would listen that he intended to live off ... Naturally, the presence of competent men from responsible American companies was highly undesirable to such people. Although we got around and overcame these situations, it is a fact that all the obstacles that were placed in our path were in the American zone. In the French zone our friends there gave us every opportunity for visitations, interrogation, and investigation. Also, in the British zone our friends there assisted us in every way. The bulk of information about the German chemical industry we obtained, therefore, came from these two zones of occupation, the French and the British. The American officials discouraged every attempt on my part to visit the Russian zone of occupation, although we did drive through the Russian sector in Berlin and we nearly drove by accident out of the British zone one evening into the Russian zone. I wish now that we had.

The commitment and determination of the American Cyanamid team was considerable, as was its stamina.

In order to get organized and circumvent the obstacles in the American zone, we divided up the work. Dr. Thurston canvassed research laboratories and research men on a limited group of subjects of particular interest to Stamford and the Insecticide Department. Most of the research men spoke English anyway. Mr. Fromholz accepted a job on one of the quadripartite committees and in this way one of our group was able to get into the Russian zone, even though he was not able to visit all the factories that he would have liked to. Dr. Parker and I undertook to find out what manufacturing processes the Germans had and especially what new developments in chemical manufacturing they had that we could use.

The two of us traveled by airplane, C&R car [Command and Reconnaissance car], weapons carrier, jeep and even occasionally by sedan about 3,600 miles from southern Baden to southern Schleswig Holstein on both the French and German sides of the River Rhine. We visited 18 different chemical factories in this enemy country, including all 7 of the various I.G. plants in these 3 zones of occupation. I interrogated over 100 enemy personnel, including their leading chemists, chemical engineers, managers, directors, etc., some of whom are in prison. Whenever possible I interrogated their foremen and operators as well. When the reports are published in Washington, there will then be available over 100 processes of manufacture from this area alone.[57]

King then gave an American's view of the German chemical industry, described how certain products compared with those made at Bound Brook, how German factories were a mix of modern and old equipment, and discussed how the German industry managed to survive Allied bombing raids, maintain postwar production, provide for the American Army of Occupation, deal with toxic benzidine, and how it was, in one division at least, plagued with internal rivalry and incriminations. Notes were also made on forced labor, referred to as displaced persons (D.P.s), the conditions of buildings after six years of war, an ingenious method for protecting buildings from bombs, processes that could be justified only by the contingencies of a war economy, processes that were very modern, and others that were inefficient.

The German chemical industry creates the impression that it is running at almost full blast. This does not mean at 100% capacity because of limitations of coal and some raw materials. It is difficult to believe that the lack of coal is due to anything but unwillingness on the part of the Germans to mine it, as they claim they are overpopulated and have plenty of people. Also, they have returnees from foreign countries. Leverkusen [Bayer], which used to employ 15,000 men, was employing last July only 13,600, and the other I.G. plants are running correspondingly. We are spending, so I am told, one billion dollars a year in the U.S. zone to help them ... At Offenbach, near Frankfurt, BON [beta-oxynaphthoic acid] was being made at the rate of about 250,000 lbs. per month. This is ten times our figure![58]

Each of these German chemical plants had its proportion of enforced labor, for example, at Darmstadt 800, of whom 400 were Russians, 25 French, 70 Italians, etc. Of course, none of these D.P.'s were around when we were there as they had all been liberated. The Germans said they were good workmen as long as they were watched. In another place where they had some enforced Dutch labor, the Germans would not permit such D.P.'s to enter the air raid shelters during an air raid. We saw many air raid shelters of many designs and the Germans said that no one was ever lost in an air raid shelter when properly built as they were in the factories. The most damage was done at Ludwigshafen [the BASF factory, on the left bank of the River Rhine] where the Germans, driven out by the Americans and having retreated to the German side [right bank] of the Rhine, lobbed mortar shells and laid artillery fire on the plant to try to delay the Americans. The Germans estimated the damage there was 20%. Nowhere else was there any comparable damage in Germany.[59]

The German chemical industry as we saw it had some interesting features. Each of the large I.G. plants was a heterogeneous conglomeration of very old obsolete shops interspersed with modern buildings and modern equipment and, as might be expected in plants as old as these are, with shops and buildings of every age and condition in between. In one plant, for example, at Ludwigshafen, they had a magnificent building standing right in the middle of the ruins of the Alizarine Red plant, etc. This six-storey building had received 4–1,000-lb. aerial bombs, and was full of porcelain equipment. All the damage done was four holes in the roof and a little local damage where the bombs exploded. The reason, the Germans said, was the ribbons of glass each about 9″ wide and extending from the ground to the roof and which relieved the pressure by blowing out. The shop was built to make chlorbenzoyl benzoic acid by an excellent continuous process with a capacity of 1,000 tons a year. It is now a monument to excellent chemical engineering based on confidence in world conquest. However, it could be put in shape and started up in a month's time! We visited plants that produced products synthetically instead of from natural raw materials at 5 times a normal cost. One such plant is running night and day and it was making caffeine said to be for Coca-Cola for the U.S. Army of Occupation! We saw the beta-naphthol plant in Hoechst running at ½ million lbs. per month and while this was not as large by any means as our own, nevertheless, it is 500,000 lbs. per month that we cannot get the naphthalene for. The Germans understand the BN [beta-naphthol] process very well and know nearly all the angles we have developed. We are ahead of them, however, in production rate, labor usage, floor space required and quality of finished product. You would laugh to see their stills.[60]

In another plant where benzidine is made, it is interesting to find that violent differences of opinion existed between the different German consuming plants on whether the benzidine should or should not be distilled. The distillation was known by them to be very poisonous and yet they kept on doing it.

Their Tobias acid process was so old, it was moldy. Not only is the quality nothing to write home about, but they use 100 lbs. BN, instead of 75 as we do, to make 100 Tobias.

In some plants they liked to work in autoclaves and in others they avoided them. The individuality of the different plants grouped together as the I.G. had a hard time dying and in spite of a most excellent system of technical organization, they lacked the human touch that brought men together and ironed out their differences. For example, Dr. Ma[h]ler who made aniline at Hoechst and Dr. Hüttner who ran the aniline plant at Ludwigshafen and Dr. Belfontaine who ran the aniline plant at Uerdingen had heard of each other and their reports were read in a common meeting to one of the technical committees, but the technical director of the whole I.G., Ter Meer, never made these men visit one another's plants and get acquainted and learn each other's problems, trials, triumphs, failures, etc., so as to be mutually helpful one to another. Instead, each accused the other of being dishonest, falsifying his accounting and cost records, etc., etc.

Notwithstanding the strong personal rivalries, King observed that each facility of the German firm was organized on similar lines to Bound Brook, with divisions (or departments), based on specific types of products, managed in the same way by technical committees.

Outside of this lack of human influence, however, the organization of their technical department was extremely efficient and thorough. Each I.G. plant had a series of technical committees much like we do covering divisions, grouped in which were manufacturing operations of analogous character. Then each plant had a top technical committee and then there were I.G. technical committees covering separate fields.

With reference to dyestuffs, the general feeling was that it was more profitable to devote their effort to lowering factory costs by improving processes than to continue to hunt for new products. Much effort in more recent years was spent in improving the cost of production of intermediates.

However, a considerable amount of attention was paid to new members of the following series: vats, indigosols, naphthols, phthalocyanines.[61]

King had also inquired into the measures for pollution control at the German dye factories. Whereas Bound Brook had to make do with dilution of its waste in a river that, at best, flowed at the rate of 90 million gallons a day, and considerably less in summer months, Bayer and BASF were enabled to take advantage of the wide, deep, fast-flowing Rhine. Even then they faced difficulties.

I had assumed that the old established chemical industry of Germany with all its vaunted efficiency would have developed an excellent system of air pollution prevention and of effluent treatment. However, when our report is issued in Washington, you will see that in the main they did nothing but depend upon dilution. Most of their plants were on the Rhine River and the volume [in] different places varies from 23 to 45 billion gallons per day at low water so they usually enjoyed dilutions of over 1,000 to 1 all year round, and our Effluent Treatment Committee will appreciate the value of such dilutions.

The Rhine River at Leverkusen [the Bayer factory] carries much turbidity and is very dirty when it arrives at the factory. It has a hardness corresponding to 120 mg CaO per liter and can neutralize 240 mg H_2SO_4 per liter. 4 m^3 of river water, therefore, will completely neutralize 1 kilo of H_2SO_4. This plant, which is about 3 times the size of Calco, puts 45,000 tons of sulfuric acid equivalent into the river every year, in other words, at the same rate we do. The Germans were very thoroughly aware of the great importance of dilution in effluent treatment and stated emphatically that any plant of that size–20 chimneys, 15,000 men, etc.–must be located on a river like the Rhine. The more serious complaints they had heretofore had were from the salmon fishermen who sampled the fish, cut out a slice, baked it, tasted it and if the taste were queer, complained. The industry was then accused of putting phenol into the water. Most of the latter's efforts were to spread the phenol discharge out over 24 hours and to prove that the river water behind the diesel driven boats was higher in phenol than their effluent. I visited many governmental agencies and was unable to find that they had any comprehensive program for control at all. Also, the I.G. paid more taxes than the salmon fishermen. While we were there, Holland officially complained against Germany that the latter was polluting the Rhine and each zone of occupation was busy trying to prove it didn't come from them! The phenol processes, especially the one from monochlorobenzene, has an effluent with 100 mg/litre of waste phenol! Their chemists and chemical engineers did good work investigating the subject and some clever treatments at the source were developed and at Wolfen where they made sulfur colors, they did develop some clever methods of treatment which I hope will be helpful in handling our Bldg. 66 job where we are treating similar sulfahydrate brines that have extraordinarily high oxygen consuming power and which come from various shops with similar thionation steps.[62]

German processes for manufacture of certain coal-tar intermediates used in the production of explosives and dyes varied in age, purpose, and efficiency. The American visitors were particularly impressed with the great extent to which a number of traditional batch processes had been successfully adapted to automated continuous operation.

In Germany we saw obsolete processes and well-developed processes and new processes and processes whose only excuse for existence was preparation for war. For example, to produce filling for bombs, DNB [dinitrobenzene] was required on a really large scale. They made it, of course, from MNB [mononitrobenzene]. In order to supply the very large demand, they developed a continuous MNB process which is very interesting and which functioned well for 8 years! When it can be released, I think you will find it an excellent piece of work. Similarly a continuous process for making chlorosulfonic acid for smoke screens was worked out and is still in operation for sulfonamides, indigosols, wetting agents and other requirements. We saw an excellent DMA [dimethylaniline] plant producing a DMA as good as ours in quality from aniline and waste dimethylether which is a waste from making methanol. It is a continuous autoclave process. Likewise, MBT [mercaptobenzothiazole], phthalonitrile, etc., were made in continuous autoclave processes. The Germans purified their benzanthrone [a vat dye intermediate] and in due course you will be able to see the high quality of this product and the unique equipment used in its purification. We saw an old, but we believe, an excellent resorcine plant and process and if we could have stayed there longer and had some help, we could undoubtedly have learned even more.

The American Cyanamid team spent two weeks writing up seven reports as its commitment to the Department of Commerce. King and Parker then left for Switzerland on Calco Chemical Division business:

We visited in Switzerland our friends at the Ciba Company in Basle and talked with them and later on were invited by the Swiss Government to visit the dynamite works where they were making gelatine powder using at the maximum rate of 5,000 lbs. of nitroglycerine per day and which was intended for the enormous hydroelectric plant at Pizzo Lucendro in San Gottardo.

They crossed the border into Italy, and embarked on a 1,500-mile journey that took in seventeen chemical manufacturing facilities.

Our friend Regalia ... arranged conferences with and visits to all the important chemical companies and also many smaller ones. For example, we visited my old friend Giacomo Fauser [of ammonia fame] who is the technical director of the Montecatini Company and who has at his disposal a magnificent technical center, including pilot plants with tools, varying from test tubes to 2,000-gallon autoclaves ... It was interesting to be told at Rhô [Bianchi & Co.] by M. Pazze, who used to be a German agent in India, that we, Calco, were the ones who had revolutionized the alizarine red business in India with our dispersible powder. This work done by the technical committee long ago was a good job, but we never heard it praised until Signor Pazze said that we reduced the costs of transportation into the interior of India so much by our powder that the whole industry there was revolutionized.[63]

The factory of Dr. Saronio at Melagano "was very well integrated and one that seethes with independence and makes everything from caustic to dyestuffs except vats and naphthols ... This company has what looks like an excellent line of leather dyes, samples of which I hope soon to be able to present to our Dye Type Committee."

In all, the trip lasted five-months, during which time the Calco representatives also visited chemical personnel and facilities in Czechoslovakia, France, Belgium, and England. Like other American investigators, the American Cyanamid group was mainly interested in new knowledge, rather than in acquiring equipment. "Our 5 months' trip was entirely too short to get all the technical information that is available. It takes much more time and, in our opinion, more people ... There is a mine of chemical information but even if we organized to go over and get it all, we couldn't absorb it anyway!"[64]

This was not the only visit to immediate postwar Germany made by American Cyanamid officers. Calco's Moses Crossley and James

H. Williams had joined technical commissions interested in developments in organic chemistry, particularly dyes and sulfa drugs.[65] While the effort in time and expense invested in these trips emphasized the perceived outstanding achievements of German science and technology, and the desire to quickly grab whatever was available, not many innovations made their way directly to the United States. This was certainly true of polymer chemistry, as historians Peter Morris and Raymond Stokes have shown, in part because the United States had made good progress since the 1930s. Few German products, apart from polyurethanes, for example, were of direct and immediate value to the civilian economy.[66]

For dye chemistry the situation was somewhat more straightforward. Once the Allied reports or other information had been reviewed, a repertoire of reactions could be selected and applied, at minimal expense on the laboratory bench, to produce samples of novel products. If a sequence of reactions looked promising, then they were scaled up. My interviews with former Calco chemists suggest that this is exactly what happened during the following years at Bound Brook. In many cases the I.G. Farben processes were successfully replicated, and often improved, though sometimes, while they were examples of excellent chemistry, there was no commercial demand for the products. A good example is Warren Forster's work on Vat Yellow R. Though the chemistry was difficult, Forster managed to improve on the German method, and file a patent; he was then informed that demand was too small. Some new textile products were recognized as being of considerable value, particularly optical bleaching agents, commercialized by I.G. Farben just before the war, but subsequently neglected. Certainly, as King pointed out, American Cyanamid technical people returned from Germany with the belief that there was much new valuable information to be had, providing that resources were available to gather and evaluate the vast array of new processes and products. Significantly, General Lucius D. Clay, military governor from March 1947, was against these civilian investigations, interpreting them as reparations in kind, with overwhelming advantages to the United States.

The Germans soon returned to the lost notion of a great chemical industry. This provided an alternative approach to knowledge transfer: direct negotiations for licensing rights with Americans and others.

The German firms would thus be encouraged to offer only technology which they already knew was viable or that held out great promise. This was favored by American Cyanamid chemical director Norman Shepard. In June 1947, the last month in which technical investigations were conducted in the British and American zones of occupation, Shepard visited the major German sites in the west. Anticipating rapid recovery by the German chemical industry, he was anxious to ascertain possibilities for obtaining licenses, purchasing chemicals, particularly dyestuffs and intermediates, and establishing and reestablishing contacts with German firms. Shepard strongly supported reconstruction of the German chemical industry, rather than dismantling and destruction of its facilities.[67]

This was a sharp reversal of the situation a year or two earlier. In 1945–46, some industrialists among the victorious western nations had preferred the reopening of German dye-making factories only to satisfy the immediate postwar shortages, and then their closure as soon as other countries were able to produce sufficient quantities of the much needed products. This was the view of the Association of British Chemical Manufacturers.[68] Not altogether different was the opinion of American Cyanamid vice president Harry L. Derby. He warned participants at the Manufacturing Chemists' Association's 1946 meeting, held at Skytop, eastern Pennsylvania, that if Germany was allowed to rehabilitate its chemical industry and retain facilities for manufacture of munitions—which included aromatic chemicals as well as nitrogen products—then it might once more become a threat to world peace. For a year or two, Allied countries did favor dismantling of German chemical industry, at least until 1947, when James S. Martin was appointed chief of the decartelization branch of the American Military Government in Germany. By the middle of that year, the first stirrings of the cold war brought about a change in political and industrial strategies that now turned to revival of the economy in the western zones.[69]

Still, there remained many questions about prewar connections, how they were used by I.G. Farben to gain access to foreign technology, and at the same time to place limits on how much the overseas associates might learn, and apply. On September 2, 1947, these connections came to the fore when, under General Telford Taylor, prosecutors of I.G. Farben directors and officials at Nuremberg placed

American Cyanamid & Chemical Corporation, a leading direct-sales agency for the German behemoth, at the head of a list of fifty-three American firms in one way or another associated with I.G. Farben. The 20,000-word indictment drawn up by American lawyers included, among other things, charges of war crimes, such as use of slave labor at the Auschwitz–Monowitz Buna rubber facility, and asserted that I.G. Farben, through cartel arrangements with U.S. firms, had prevented shipments of essential war materials to Britain and held back American firms from contributing to defense-related industries. American industrialists responded that the contacts had, through acquisition of information about novel processes, greatly strengthened rather than weakened the war potential of the United States. While American Cyanamid had less prewar connection with I.G. Farben than, for example, Standard Oil of New Jersey and DuPont, it was, by this association and price-fixing of dyes, tarred with the same brush by those with political axes to grind, such as Howard Ambruster in his conspiracy-minded *Treason's Peace: German Dyes and American Dupes.*[70]

Despite dismantling of facilities used in making war materials, and removal of plant as reparations, particularly in the Soviet zone, the production capacities of German dye and chemical factories in western zones—under Allied tutelage—were soon returned to almost prewar levels. In the spring of 1947, agreement was drawn up for deliveries of chemicals between the American, British, and French zones. The cold war halted further dismantling and dispersal of assets and the breaking up of the "vast trust," at least in the west. On November 10–11, 1949, representatives of the United States, Britain, and France meeting in Paris agreed to remove German factories from the reparations list. In the case of BASF Ludwigshafen, the only exception would be the synthetic ammonia and methanol facilities.

The reemergence of the German chemical industry followed the separation of I.G. Farben into its pre-1925 constituent units, in accord with Allied High Commission Law no. 35 of August 17, 1950. During December 1951–January 1952, the new successors, once more known as BASF, Bayer, and Hoechst, were formed. AGFA, whose Wolfen plant was in the Soviet zone, was reestablished at Leverkusen, merged with Bayer. In 1953, the occupation of the western zone of Germany came to an end, and the German synthetic-dye industry, though shorn of foreign assets and confronted with unprecedented competition, was once more about to become the largest in the world.[71] Within four decades, Bound Brook's dye technology, some of it borrowed from I.G. Farben, would be handed over to BASF's American subsidiary.

Chapter 5

Postwar Changes and Markets

> "Prior to the last war our exports of Calco products were extremely small. During the war, and immediately thereafter, the export demand was many times greater than we could supply, but we knew, of course, that much of this demand would disappear with the rebuilding of damaged plants in Europe, Japan, Russia and the satellite countries."—Sidney M. Moody, Far East–American Council Conference, October 1952.

American Cyanamid's immediate postwar efforts, including in R&D, were concentrated on integrating wartime innovations into civilian markets using similar high-volume production processes. The new products included: sulfa drugs; Beetle molding resin powder and Urac urea-formaldehyde resin adhesives; Melmac molding powder, melamine laminates, and Melurac adhesives; acrylonitrile and rubber chemicals; lubricating oil additives and petroleum cracking catalysts; crop-protection chemicals and defoliants; and mineral dressing reagents. Several originated at or were connected with Bound Brook. American Cyanamid also converted methanol into formaldehyde, a vital ingredient in the amino resin processes.[1] The novel crop-protection products included the organophosphate compounds parathion (1947), claimed to be five to twenty-five times more powerful than DDT, and malathion (1950). These were derivatives of I.G. Farben research into insecticides, from which nerve agents were discovered. American Cyanamid was the first corporation to exploit these discoveries for agricultural purposes, no doubt as a result of Dr. Thurston's enquiries in Germany during the summer of 1946.

New Needs

Shortages of textiles and other goods, including abroad, meant that Calco was encouraged to maintain production at high levels, even if not equal to those of the war years. New markets, many outside the United States, were waiting to be exploited, a challenge presented to Calco Dyestuff Department manager J. Pfister. Dye sales were promoted through the creation in 1946 of a Canadian subsidiary of American Cyanamid, also known as the Calco Chemical Division, with offices and warehouses in Montreal and Toronto. Fraser M. Moffat Jr. was appointed manager of the busy Calco Export Department early in 1947.

Rapid wartime developments in instrumentation needed to be incorporated into both production and research. Worn-out process equipment had to be replaced, and new buildings erected.[2] There was plenty for returning and new chemists to do. Those coming back to Bound Brook from war service included former student trainee Henry A. Molt, who held a B.S., majoring in chemical engineering, from Michigan State College. Molt joined Calco in 1937, and until 1942 was with Department A (intermediates) engineering staff. During 1942–45 he served in the Army Quartermaster Corps as a major, and in April 1946 rejoined Department A. On July 1, 1947, Molt was appointed engineer with Department R (rubber chemicals). Another returnee, as a major in the Reserve Corps, was Wendel Munro, who from April 1942 to November 1945 had served with Technical Command, Edgewood Arsenal, in charge of smoke munitions.

A new member of staff in 1945 was Eugene Murray Allen, previously a research chemist at Picatinny Arsenal (1942–45), before that at United Color & Pigment Co., and earlier at E. R. Squibb & Sons. At Bound Brook he undertook research into analytical and physical chemistry, before moving on, in the 1950s, to instrument-based studies, including, with Stearns, spectrophotometry, color specification, and thin-film optics.[3] Another Allen, William Allen, joined Bound Brook in 1945, and undertook research in analytical chemistry. Previously he had worked with the DuPont Atomic Energy Project.

Some older chemists retired shortly after the war. They included, in October 1945, production manager N. Arthur Laury, an authority on heavy chemical manufacture, particularly inorganic acids. He graduated from the University of Vermont in 1898 and then worked for General Chemical Company (New York) prior to joining Calco in 1927. After a tour of European acid factories, he managed the

Bound Brook acid operations and worked on novel processes, including a new vanadium catalyst formulation for the manufacture of sulfuric acid by the contact process. The patent was filed on August 28, 1928, and, with other catalytic processes from Calco, Selden, and American Cyanamid, was assigned to a subsidiary, Catalytic Process Corporation, founded in 1929. Laury's catalyst was employed in a 100-ton acid plant at Calco.[4]

In the capable hands of Elizabeth J. Cole and staff, Bound Brook had built up "[o]ne of the country's outstanding industrial libraries."[5] In the summer of 1946, Cole was elected president of the Special Libraries Association at its annual conference in Boston. She had served as chair of the science–technology group, president of the New Jersey Chapter, chair of the publications governing committee, and editor of the Union List of periodicals in the chemistry section of the association. The library and information services were almost overwhelmed with reports of new discoveries and the influx of reports of Allied investigators. These were sorted out, cataloged, and often summarized.

Additional chemists and process engineers were needed to analyze information and handle the transfer of German and other processes to a Bound Brook that was gearing up to serve a booming civilian economy. This included renewed demand for a rainbow of dyestuffs that offered a break from the drab colors of the war years. Production was assisted by the release of 12 million gallons of toluene by the War Assets Administration early in 1946, the year in which Erwin Klingsberg, Isaiah Von, and Robert Francis Bann joined Bound Brook. Bann received his B.S., majoring in chemistry, from Illinois in 1943, and then joined the newly opened laboratories at Camp Detrick, Maryland, where he worked on biological warfare agents. His long career at Bound Brook began as a dyes development chemist. He obtained his master's degree from Rutgers in 1959.

In 1946, William Bell announced plans for enlargement at six American Cyanamid sites, including the greenfield Willow Island facility. However, as the Department of Commerce observed, high building costs and limitations on non-residential construction caused cancellations, cutbacks, and curtailment in the expansion plans of chemical industry. Despite this, American Cyanamid reorganized in readiness for future growth. On July 31, 1946, American Cyanamid

& Chemical Corporation was consolidated with the parent company as the Industrial Chemicals Division, and on September 1, Lederle also underwent consolidation with the parent. American chemical industry was in an expansive mood. So were European firms, including Britain's ICI, which announced a 9 million sterling investment in new dyestuff manufacturing facilities. In 1947, GAF, which had been sequestered by the U.S. government during the war, was preparing to embark on a $15 million expansion of its dye-making facilities. Massive demands for dyes and pigments (organic and inorganic), the latter used in paper, inks and paints, were anticipated, in part to make up for years of dullness and neglect. Thus, in 1947, U.S. railroads announced that they intended to spend $100 million on the repainting of rolling stock.

Also in 1946, Calco created the post of research fellow, that, as with the research associate, was an incentive for keeping outstanding scientists in the laboratory. These posts, of which the fellow was more senior, were equivalent to executive positions in research supervision, and research direction and management, respectively. The first research fellow was Dale Eberhart, a research chemist since 1935. He held this post for four years, until 1950, when he became a development group leader, followed in 1955 by promotion to senior chemist. Eberhart specialized in azo dyes, optical bleaching agents, and plant-growth chemicals. Production at Calco-associated facilities was assisted by transfer of specialists from Bound Brook. Glenn S. Watson, assistant divisional chief chemist, was appointed chief chemist at the Marietta, Ohio, facility, under general manager G. A. LaVallee.

Calco ran intensive one-year technical training courses for new chemistry and chemical engineering graduates joining Bound Brook. Twenty-four new hires, representing "19 different colleges and universities from all over the country, from the University of Colorado to the University of Maine," reported for work on July 1, 1947, and were immediately put through "an extensive orientation program … directed by R. N. Paulson, assistant manager of Methods Engineering."[6] They helped to boost dyes made in America tenfold when compared with 1939 production. This was despite shortages of benzene and phenol in the United States, and of U.S. dollars in countries clamoring for dyes.

Vanderwaart's wealth of memories humanized stories of life at the bench and on the shop floor at Bound Brook during this period of growth: "We also made vitamins, folic acid and methyl textrate. We were bulk chemical manufacturers. Lederle made the tablets, capsules, ointments, suspensions for the retail trade. Harvey Whitten, Jim Needles and Ed Soriano were with me. Jim's calculations were always messy and I was afraid that it was a mess inside his head as well ... Harvey Whitten was a competent lad. We often referred to the folic acid shop as the 'Whitten Pharmaceutical Co.' This was a very satisfying assignment for there was no doubt that we were contributing to the public welfare."[7]

Then there was the sulfur color shop, building 66, where Myron Singer was in charge. "I jokingly said to him that sulfur colors were no big deal. You took any organic compound off the shelf, cooked it up with sodium polysulfide, evaporated it to dryness, put it in drums and took other people's good money for it. I said 'You probably could make sulfur brown out of horse shit.' He exploded, 'You can make very good sulfur brown out of horse shit. The trouble is you cannot control the shade.' Sulfur colors are relatively dark and have poor light resistance. Hence they find use in casket linings."[8]

After the war, shortages of qualified scientific staff and social pressures further lowered barriers to laboratory entry for both men and women of different backgrounds. As Von points out, "Calco hired chemists without bias. I think about a dozen Jewish chemists were employed (including me), some in R&D and some as plant chemists in 1946–1950." Erwin Klingsberg states that Hans Lecher was responsible for the entry of many of the Jewish scientists into the Calco Chemical Division. They made substantial contributions toward research and manufacture, some joined technical committees, and others became departmental and divisional managers. Included were Jason Melvin Salsbury and Samuel Michael Gerber. In 1946, organic chemist Jason Salsbury (Ph.D., University of Virginia) joined Bound Brook, where he undertook research into textile resins. He was later appointed a research manager. When he left the facility in 1957 it was to take up a new post at American Cyanamid. We meet him again, as head of research at the Chemical Research Division, created in 1972, in chapters 7 and 8. Samuel Gerber received his Ph.D. from Columbia University in 1948, and joined Bound Brook in 1951.

He was appointed assistant technical director, Organic Chemicals Division, in 1956, chief chemist of the division in 1968, and manager of dyes and chemicals research and development, Chemical Research Division, in 1974 (he retired in 1980).

The Textile Resin Department was managed from the fall of 1946 by Kenneth H. Barnard, previously at Pacific Mills. In 1947, Barnard announced the availability of a new thermosetting resin that gave a moire finish to fabrics. At this time, amino resins were the most useful thermosetting products employed in textile finishing.

Industrial Relations

For many unskilled and semiskilled shop-floor employees the prospects were not so bright or exciting. The cessation of hostilities brought about a slowdown in the hectic nonstop pace of wartime production. Of the around 5,000 employees, only 4,000, the same number as at the end of the 1930s, were now required for peacetime production. Von explains how management tackled the situation through the Industrial Relations Department, created in 1946, and managed by H. D. Acaster:

> Calco had a union and the management wanted to avoid riling them up. An arrangement was made where the union would accept lay-offs without causing trouble in exchange for an incentive system to benefit the remaining employees. Every process in the plant would be divided into steps of approximately equal labor input as determined by a newly established industrial relations department. Each building contained a number of "shops," each consisting of 10–20 men. If the men in each group carried out a number of [production] steps which exceeded a norm, all of the men would be rewarded with a bonus.

There was a major, and unforeseen, downside to this arrangement that would, without correction, plague the factory until the end. This arose because there "were considerable administrative costs involved, and no standard was set for quality of production. Thus if an operator at night saw something unusual with a batch, pretended not to see it and kept on going instead of waiting for a chemist or supervisor in the morning, he would have run more steps and earned his group more credits towards the incentive. This backwards system was in use for the last 30 years of the plant." One other benefit accruing to remaining workers from the new arrangement with management was the introduction of a pension scheme in 1945. Salary agreements were reviewed annually with union representatives. For example, in 1949, the hourly working rate was increased by 9 cents, and increases were also granted in the hourly rates for those working afternoon and night shifts, and at weekends.

Product Changes

Reduced output from war-torn and rundown European factories provided new export opportunities for American chemical industry, particularly at a diversified site such as Bound Brook. Renewals, further expansion, and more care in recovery of valuable chemicals became important now that peacetime trading conditions, with the need to maximize profits from sales, had returned. The old, corroded hydrochloric acid (muriatic acid) plant was demolished, creating a temporary but urgent need for alternative supplies. For five months, acid "tank cars came in from such widely separated places as Alabama, Texas and Massachusetts." One outcome was that hydrochloric acid used in the manufacture of a sulfa drug intermediate was recovered, instead of going to waste as previously.

The Calco Chemical Division returned to research and development work on dyes, pigments, intermediates, certain synthetic routes to pharmaceuticals, and chemicals employed in processing of rubber and plastics. The sulfa drugs business, however, began to suffer from the increased availability of penicillin for civilian use. Also, in March 1947, a board of adjudication appointed by the American Arbitration Association ruled that American Cyanamid should pay royalties on sulfadiazine (sulfapyrimidine) amounting to $1,750,000 to Sharp & Dohme, Inc., arising from a dispute over their 1941 contract related to patents for the drug. Then on October 27, the War Assets Administration offered its entire inventory of sulfa drugs, valued at $2.5 million, for sale, though at fixed prices, which aided market stability. Thereafter, the market for sulfa drugs increased only for veterinary use, which was considerable, and became an important export activity at Bound Brook.

Growing output and competition among manufacturers made necessary a further intake of chemists, including, in 1951, Gilmore Trower Fitchett (Ph.D., University of Virginia, 1951), who joined the Pharmaceutical Department as development chemist, and in 1952, Robert Jacob Alheim (Ph.D., Yale, 1953), who worked on organic pigments.

In some sectors, shortages were much in evidence, which led to a black-market trade in dyes. Calco's Pfister warned in no uncertain terms that the firm's policy was to discourage such profiteering, and it would immediately cut off supplies to any purchaser found to be engaged in the black market.[9] Demand was great for Calco's Pepton 22 plasticizer used in GR-S (Government Rubber-Styrene) and crude rubbers. By 1952, Calco Bound Brook was the largest producer of stable accelerators and rubber additives in the United States, providing one-third of MBTS, two-thirds of Zenite, one-tenth of MBT, and all the Pepton plasticizers and the non-staining antioxidant known as AO2246.[10]

The introduction of several new manufacturing processes required complete reorganization of pilot-plant operations. In 1945, Bound Brook centralized its pilot-plant activities for all manufacturing areas, in order to "ease and hasten the passage of a product or process from the laboratory to commercial plant operation ... the Central Pilot Plant is used by an organization producing about 1,000 different synthetic organic chemicals—mainly intermediates, dyes, pigments, textile resins, pharmaceuticals, and rubber chemicals. The majority of these chemical products are produced in batch-type reactors, followed by various methods of isolation from solution, after which they are dried, ground, blended, and packaged."[11] The main feature of the Central Pilot Plant was flexibility and adaptability.

Typical of processes developed in the pilot plant were those for Calco's vat-dye intermediates, which provided an enlarged range of postwar colorants. They were described before the Calco Chief Chemists' Club in September 1948 by Wendell Munro, who emphasized a novel catalytic route to the highly regarded Calco Copper Brown.[12] Vat dyes were poorly soluble in water, and generally applied in the more soluble reduced, or leuco, form, in which color was lost.

The color was restored by oxidation. A form of vat colorant better suited to users was much desired. A new Bound Brook process, borrowing from I.G. Farben technology—and patented in 1946 by Lecher's section, including section leader Mario Scalera and Elizabeth Hardy—afforded soluble vats, the sulfate esters of leuco compounds, made, significantly, directly in aqueous media. Thus "[w]hereas the classical synthesis involves isolation of the leuco and esterification in pyridine, Calco's process permits the ester to be formed in the aqueous solution in which the leuco is formed by reduction." Other contributors, supervised by Scalera, included William B. Hardy and Isaiah Von, assisted from late 1948 to October 1949 by Marie L. Cline, who held a bachelor's degree, with distinction in chemistry, from Cornell (1948). Vat dyes, as the most complicated dyes to synthesize and apply, certainly presented many challenges. Scalera was a section leader, dyes and pigments research, during 1943–48, after which he was promoted to assistant to the research director.

Despite the optimistic tone of Munro's presentation, Calco's soluble vats based on the aqueous process were, as Von points out, to be short-lived. These colorants were introduced to dye users by Bound Brook around 1950, after several years of research. According to Von,

> About 5–10 chemist years was devoted to this. It was my first assignment when I joined Calco in 1946. The process invented using water instead of pyridine was quite novel and might actually have been cheaper if it had gone into full development. There were several flaws, however. The aqueous process did not work on the complete line of vats the way the pyridine process worked. There was little sales demand for these products. They were very expensive. In the meantime DuPont had come out with improved vat dyeing technology helping to put Calco Soluble Vats at a greater disadvantage. Production carried on in fits and starts until 1952. Then a batch of Jade Green soluble vat packed in two drums and worth about $10,000 was somehow lost in the plant and undoubtedly thrown out. This settled matters; we discontinued our soluble vat sales.[13]

In December 1949, plant engineer R. L. Cassell announced a number of promotions, including of Victor E. Stilwell, who became assistant plant engineer with responsibilites for Departments A, I, N, P, R, the effluent department, and what was still known as the Heller

& Merz Department, based at Newark. The Newark facility continued to specialize in paper dyes, including the Helmerco colors, ultramarine, and various organic pigments. Along with the Calcotones and other Calco products, their growing uses were extended by the investigations of the Application Research Department.[14]

Calco's anthraquinone was made from Selden's phthalic anhydride and benzene in a Friedel–Crafts reaction to form *o*-benzoylbenzoic acid in ball mills. The ring closure to anthraquinone took place in sulfuric acid and sublimation afforded a "pure, pretty looking product." Calco supplied most of the smaller dye companies, and some larger ones such as GAF, with anthraquinone. Von points out that while Selden had the first modern plant in the United States for phthalic anhydride, it was not improved, as was done elsewhere, particularly in the petrochemical industry, where novel catalysts and processes had been developed. For example, Munro in his 1948 talk had drawn attention to then recently patented Socony-Vacuum Oil Company's continuous-phase catalytic process.[15] The lack of improvement at Selden and the system of internal charging at American Cyanamid eventually ruined its phthalic anhydride business.[16] Von explains that phthalic anhydride was transferred at cost to Bound Brook. "I believe it was standard practice to transfer at cost from department to department and division to division, which was one of the management defects. In the mid-1950s a price war broke out for phthalic anhydride, since by then there were a number of more modern plants in operation. We purchased our phthalic from Selden at 16 cents/lb. when the lowest market price was about 9 cents. This eventually forced Selden out of this business ... Cyanamid could obviously not compete, with their older plant."

Dye Research: Allied Surveys, Patents, and DuPont Products

According to Erwin Klingsberg, Jeffcott was never very happy with Crossley, and Lecher's promotion to head of research in a dye section was in anticipation that he might reinvigorate dye discoveries, something that may have been neglected by Crossley. Whatever the truth, it was the fact that Crossley and Lecher were "at each other's throats from day one" that to some extent determined the direction of Klingsberg's career at Bound Brook. Klingsberg originally undertook patent work for Lecher, as well as review of BIOS (British Intelligence Objectives Subcommittee) and FIAT reports and literature research. His work with patents involved preparation of records of inventions and disclosures for submission to Stamford, where complete patent specifications were written up.[17]

Klingsberg spent most of his time in the research library, situated in building 10, where the dye-research laboratory was located. In the normal course of events, he would have expected to advance from dye to pharmaceutical patents, connected with activities in building 40, where the pharmaceutical research laboratory—Crossley's territory—was located. Certainly Klingsberg's prior work at Schering was reason enough to enable a smooth changeover to pharmaceuticals. However, because of the great enmity between Crossley and Lecher, this was not even remotely possible. So Klingsberg decided to undertake bench research. When he asked Lecher's permission for transfer to the dyestuffs laboratory, the latter became angry. Lecher handed Klingsberg a dismissal notice, but it was little more than a mild threat. He convinced Klingsberg of the need to continue the desk work, which was important for political reasons. This was connected to the fact that if Klingsberg was moved to the bench, then Stamford would take over all patent documentation work. This Lecher was anxious to avoid.

Among those on the receiving end at Stamford were patent attorneys Robert Ames Norton, Elmer Harmon, a certain Newman ("unbelievably loquacious," according to Klingsberg), and Charles L. Harness. The latter is better known as a science-fiction writer, who in 1980 published a novel, *The Catalyst*, based on the American Cyanamid chemist Johnstone Sinnott Mackay, befriended by Harness while at Stamford during 1947–53.[18] According to Harness, Mackay (John Serane in the novel), "simultaneously feared and detested the American Cyanamid management. He invented when he was not supposed to invent, and failed to invent when he was supposed to! He kept the Patent Department busy all by himself."[19] This is in many ways consonant with Erwin Klingsberg's subsequent sojourn at Bound Brook as a research chemist and inventor, described in chapter 8.

The result of Klingsberg remaining deskbound was that his workload was not at all demanding, so he turned increasingly to general literature researches, the outcome being extensive review articles, including on pyridine. Eventually, in the early 1950s, not long before Lecher retired, Klingsberg undertook synthetic laboratory work on dyes. The research consisted of investigating dyes of competitors, particularly DuPont. Klingsberg's first research publication dealt with a relevant topic, the analysis of vat dyes. Unlike water-soluble dyes, vat dyes were difficult to analyze by paper chromatography, at least until Klingsberg solved the problem. This work was considered so useful and elegant by the editor of the British *Journal of the Society of Dyers and Colourists* that he arranged for the chromatograms to be reproduced as full-color half-tones, which must have been unique for this journal in the early 1950s.[20]

Isaiah Von spent his first seven years at Calco in vat-dye research, followed by three years as group leader in the plant-process development group. Von and Klingsberg point out that invention and innovation remained mainly imitative. Immediately after the war, Von remembers, "the vat dye line was pretty much set with only 4 or 5 major vats missing, and these were added during the next few years … most of the processes [had come] from the small companies that Calco acquired, or were developed in-house from existing literature." Von's recollection is that "we borrowed from FIAT and BIOS … on the few dyes we introduced after 1946." Jay Leavitt also recalls that vat-dye innovation was achieved in "a copying sort of way," often after scouring the various Allied reports. His own research involved changes and modifications to processes, and work on stabilized azo dyes and aniline-formaldehyde derivatives. Since the Calco Chemical Division's patent applications described processes that were not always entirely novel, the patent game became what Leavitt describes as a "battle of wits."[21]

Like Klingsberg, Von was engaged in the analysis of competitors' dyes, including the products of DuPont. As an example, he was assigned the job of establishing the constitution of DuPont's Olive Green B. He was unable to solve this problem until by chance he discussed it with Klingsberg, who suggested that his recently developed chromatographic method for vat-dye analysis might assist.[22] This was duly applied to Olive Green B, and the DuPont product was revealed to have its distinctive color through shading with Jade Green.

Improved processes of azo-dye production were also investigated. Since the 1860s, the reactions had been conducted at temperatures just above freezing point, which created enormous demand for ice. Calco chemists successfully managed to bring about many of the reactions without the need for so much ice. "There was a time when all diazotizations and couplings, for example, were done at 0 to −5 °C. Careful studies permitted us to employ higher temperatures and to save many thousands of dollars in cost of refrigeration or of ice."[23]

Some dye research was less than spectacular. Lecher set up what Klingsberg called "the School of Ethyl Chemistry." Apparently Lecher had decided to assign one laboratory to work on ethylbenzene analogues of toluene intermediates. By around 1945–46, there were already some thirty patents pending in the area of ethylbenzene dye chemistry. "In most cases their superiority was nonexistent. Practically all the patents were rejected." According to Von, "Lecher also favored methyl derivatives of standard vat dyes. We worked on so many homologs that I called our lab the 'Home of Homologous Chemistry.' Lecher provided many suggestions that we had to work on; we had relatively little time to work on independent projects."

In July 1947, Robert Parker, who had collaborated in sulfonamide research, and in 1946 accompanied King on the trip to Germany, was appointed assistant research director under Lecher, who had by then become interested in the more promising optical bleaching agents—again based on prewar I.G. Farben products—for incorporation into laundry soaps and detergents.[24] In the area of optical bleaches, or white dyes, recalls Leavitt, Bound Brook "made some pretty good ones, and American Cyanamid was a factor in the whitener industry for many years." Von's recollection is that "Calco was actually the leader in optical bleaches for a few years beginning in 1947, controlling half the market. While Calco rested on its oars, others like CIBA [from 1949–50] were working furiously and Calco's share dropped to around 20%." Nevertheless a number of new and improved fluorescent brightening agents for soap, textile, and paper applications had been developed at Bound Brook. In 1948, Millson and Stearns measured absorption curves to assist prediction of the effects obtained with fluorescent dyes. Dr. Byron L. West was one of the Calco experts in optical bleaches.[25]

With expansion of the plant, an increasingly strict organizational hierarchy was established, not unlike the German model that King and colleagues had studied in 1946. Around 1948, the Bound Brook factory was divided into sections, each under the control of production and maintenance managers. These sections approximated to the departments, which some eventually became. Safety committees were established, chaired by the plant manager, and consisting of general superintendents (in charge of departments) and superintendents (in charge of buildings), with representatives from engineering, laboratories, maintenance, industrial hygiene, and safety.

American Cyanamid's sales in 1947 totaled $215 million, which included $32 million of resale. This compared with DuPont at $783 million, Union Carbide at $522 million, and Allied Chemical & Dye at $365 million, figures that represented all-time highs. In 1948, the production of synthetic dyes in the United States reached 220 million lbs., the highest figure ever, exceeding production anywhere. The United States was now the world's main exporter of dyes. Nevertheless, the possibility of German revival in dye making and the dollar credit shortage were matters of considerable concern. To further promote its synthetic dyes, in 1948 Calco produced the 16-mm color film *Portrait of an Industry* that reviewed dye progress since the time of William Perkin.[26]

Around 1950, work began on a modern sales and application laboratory for dyes, building 3, located on the Hill Property. Over the next two decades, the Hill Property was to become the site of new R&D laboratories, an early example of the postwar trend toward modern, highly visible and extensive facilities, set apart from manufacturing areas, though in this case close enough to allow much useful interaction with the factory. In 1950, American Cyanamid spent $10 million on research, including at the New Product Development Department.

Careers, Honors, and Growth

Crossley, the chief chemist in 1918, director of research from 1936, and Lecher's bitter enemy, on May 2, 1947, received the Gold Medal of the American Institute of Chemists at its annual meeting held in

New York, "in recognition of scientific work and leadership in research," and efforts on behalf of the profession of chemist. In his acceptance speech he discussed the importance of research, and suggested that a fraction of those resources devoted to the atomic bomb would solve the greatest medical problems, including cancer. During 1944–47, Crossley had been assisted by Elmore Northey, who in 1948 joined Stamford as administrative director. At Bound Brook, Northey's place was taken by Robert Parker, who was transferred from Lecher's group. In recognition of Northey's achievements, particularly his work on sulfonamides at Bound Brook, in 1955 he received the Award of the Honor Scroll of the New Jersey Chapter, American Institute of Chemists (May 5), and the Outstanding Achievement Award of the University of Minnesota (September 14). Late in the 1950s, Northey met with an unfortunate driving accident: "[H]e was going under an overpass, a car fell off the overpass and hit him. He was severely injured, both physically and mentally."

Crossley retired on August 1, 1949, and joined Rutgers University's Bureau of Biological Research. For a few years, he was a special consultant to R&D sections at Calco and American Cyanamid. On Crossley's retirement, Lecher was appointed director of research. Later an American Cyanamid editor did not miss the chance to trumpet that Crossley and Lecher "appeared in *World Biography*, the largest international biographical reference book," nor that Arnold Davis was listed among the 100 top contributors to the world's rubber literature for the period 1932–58.[27]

Also in 1949, Kenneth H. Klipstein, involved in process improvements since 1933, and who "as assistant general manager had been placed in charge of the development effort in 1947," became head of the new Research and Development Department that brought together research, process development, and dyes technical service. Later in 1949 this department became known as the Technical Department, since it incorporated the chemical engineering activities of the Engineering Department. The Technical Department consisted of three sections, the Chemical Research Department, the Process Engineering Department, and the Application Research Department. Roy Kienle was in charge of Application Research. Process Engineering was further broken down into the Chemical Engineering

Department and the Process Development Department. The work of the chemical and process engineers included finding new catalysts, seeking out better solvents, and separating into component parts the manufacturing processes. The latter provided specifications for each unit operation, or subdivision, and unit process. These were then brought together on a flowsheet that provided the information required to determine capital costs.

In December 1949, chief engineer R. L. Cassell announced a number of new appointments in the Engineering Department, including Russell McCarty, as department engineer for two manufacturing departments and Damascus. In the same month, William Hardy was appointed sectional director, or section leader, in the Chemical Research Department, reporting to assistant director of research Mario Scalera. Until 1953, when he became manager of Chemicals and Intermediates Research, Hardy supervised research into azoic colors, vats, solubilized dyes, and dye intermediates. In the fall of 1952, the Chemical Research and Application Research Departments were merged to create the Research Department, headed by Parker and reporting to Klipstein. Lecher retired in 1952, and Von remembers that he "stayed on ... as a consultant. During this time he was frequently a lunch companion in the plant cafeteria. He was very charming, relaxed, and good company."

In 1951, John E. Gordon joined Calco from a teaching post at William and Mary College in Richmond, Virginia. His career at Bound Brook is a further example of the frequent and smooth changeovers that chemists made between pharmaceuticals and dyes because of the similarity of intermediates and processes. He originally worked in the Pharmaceutical Department (where studies on sulfonamide processes remained important), then moved on to Department G, vat dyes, prior to becoming chief chemist for dyes. In 1968 he returned to pharmaceuticals, where he remained until 1981, when he became manager of intermediates used in pigment manufacture, the last activity in colorant production at Bound Brook. Gordon remained at this post until pigments were closed down in 1982, when he left the facility.

American Cyanamid's contributions to the growth of the chemical industry were measured not only in terms of innovations and profits, but also in the accolades from other manufacturers. The corporation's president, William B. Bell, was awarded chemical industry medals by the American Section of the Society of Chemical Industry (1949), and the Manufacturing Chemists' Association (1950). The MCA's centenary handbook noted that in 1922 he "became president of a firm whose gross sales were only \$5 million—American Cyanamid Company. Just before his death in 1950 sales had climbed to \$240 million and the company was producing 5,000 items serving more than 200 industries."[28]

Bell died on December 20, 1950, and in the following January, Raymond G. Gaugler was appointed president. This was a short-lived post that ended with his death in January 1952, after which Kenneth C. Towe, Bell's biographer, became president. Von observes, perhaps wryly (his comments were received by electronic mail), that "neither Bell, Gaugler or Towe had any technical background, unlike the three du Pont brothers who ran DuPont at that time (two of them went to MIT and the third studied chemistry at the University of Pennsylvania)."

An Indian Enterprise

When, through its Chemical Construction Corporation, American Cyanamid engaged in foreign investments and joint projects, the Calco Chemical Division's expertise was often critical. American Cyanamid assisted in the establishment of one manufacturing facility in Chile. Another was planned for China, for which a Chinese group visited Bound Brook. However, this project was abandoned when the communists came to power. American industrial aid and collaboration was aggressively aimed at former colonies of European nations. Like other American corporations, American Cyanamid installed itself in all regions from which Britain withdrew. As early as 1945, Moody had an eye on India. Chemists from this newly independent nation studied the operations at Bound Brook, and later engaged in the manufacture of dyes and sulfonamides, as well as the vitamin folic acid, for Atul Products, Ltd, founded in 1947 in Gujarat, north of Bombay. In the same year, Lederle Laboratories (India) Ltd was incorporated.

Calco had originally provided the Indians with dye processes and intermediates, including the intermediate from which sulfadiazine was manufactured. With Calco's help, several new processes were introduced into India. King's 1953 description of an opening ceremony at Atul left a lasting impression of modern ambitions and timeless traditions. Though his many travels had made him adept at bridging business cultures, this event was both a culture shock and a remarkable demonstration of reverence afforded to novel machinery, in this case supplied by Calco. The ancestral ritual in which King was a key participant was perhaps the March 17, 1952, inauguration by Prime Minister Jawaharlal Nehru of an Atul sulfur-black and direct-dyes plant. On the same occasion, Nehru was garlanded by Sidney Moody.

In India, one goes through 3 language regions, just riding 180 miles north from Bombay ... then when you get there, you find some of the workmen speak none of these, but some other languages! To get on the necessary friendly basis, attention must be given not to offend local customs. Otherwise, there is liable to be an annoying lack of cooperation. For example, we were all ready to start one important operation in expensive, imported enamel equipment, with expensive imported raw materials, and laid our plans to begin at 6 A.M. To our surprise, the whole organization, including the top brass, also showed up, and we were asked to act as High Priests in propitiating the gods and idols, in accordance with their beliefs and superstitions.

We acceded to this interruption as graciously as possible, took off our hats, and were instructed by their priest what to do. Can you imagine a series of acolytes approaching me, each with a tray bearing something to be used in the ritual? First, our nice clean equipment was sprinkled with a sacred red powder. Then, from another tray a putty-like mass of sugar was used to stick some on each tool. Then, from another tray, coriander seeds were sprinkled on the sticky sugar. Then, from more bearers, a series of garlands of really beautiful, exquisitely fragrant flowers were handed to me, to drape on the motors, kettles, etc. It was quite a sight. Then the last bearer approached, and with much bowing, presented a small, carefully chosen, ripe cocoanut. This I raised toward the Powers above, then, on my knees, smashed it with one wallop on the concrete floor, then sprinkled the water onto the red powder on the machinery. It seemed the gods were pleased that the cocoanut was cracked by one blow. Anyway, as a result, everything ran beautifully, we had excellent cooperation, and the plant has been running well ever since.[29]

The status of Bound Brook in dye invention had attracted numerous notable guests, including in the 1950s the great Indian chemist, and expert on dyes, Krishnasamy Venkataraman. Venkataraman had also visited Germany after the war, and relied on the FIAT and BIOS reports for his famous two-volume work *The Chemistry of Synthetic Dyes* that was to inaugurate a series of volumes.[30] He was a guest at Klingsberg's home, where they discussed the possibility of sending Indian graduates to Bound Brook for advanced training and research. Though this did not take place, it would certainly have eased the pressure on the Calco research laboratories at a time of shortages in suitable American-trained chemistry graduates.

Apart from India and Chile, Chemical Construction installed manufacturing plant, mainly for nitrogen fertilizer, in Egypt, Israel, Mexico, and the Philippines.

Dyes and Resins for all Seasons and Reasons

Dyestuffs continued to represent a major part of Bound Brook's output. Classified according to use, around 1950 they included: direct dyes, *Calcomine*; basic dyes, *Calcozine*; sulfur, *Calcogene*; vat, *Calcosol* (soluble vats) and *Calcoloid*; and diazotized and azoic dyes for cotton. Calco colorants were employed in textiles, paper, printing ink, paint, leather, gasoline, wood stain, carbon paper, food products, furs, and cosmetics. Applications of Calco pigments to polymers were studied at the new Plastics and Resins Division, managed by James L. Rodgers Jr.

In 1949, Superset resin finish that possessed anti-wrinkle properties was introduced. In the same year, American Cyanamid set up the New Product Development Department that investigated sales potential for newly discovered products and undertook market research on available products. L. P. Moore, who from 1946 had been European technical representative, was appointed manager of the department. The expansion in demand for resins, laminates and other surface coatings, adhesives, and products for treatment of paper, leather, and synthetic and natural textiles provided the stimulus for major expansions in melamine-formaldehyde and urea-formaldehyde condensates at Wallingford, which was enlarged in the early 1950s,

The Bound Brook factory from the southwest, around 1950. Hill Property is in the distance, with Van Horne House and the then new laboratory building no. 3. (Fairchild Aerial Surveys/Edelstein Library.)

and also for manufacture of these products at the Willow Island factory, then an 800-acre site, and later enlarged to 1,100 acres.

The Calco Chemical Division purchased (in April 1945), built, and operated the first section of Willow Island, five buildings and a powerhouse, where it manufactured: melamine for resins; folic acid; the inorganic pigments iron blue (Prussian blue), chrome yellow (lead chromate), chrome green (a mixture of chrome yellow and Prussian blue), and chrome orange (lead chromate and basic lead chromate);

and a stilbene dye used as a textile brightener. For a time during 1947 work was stopped at the site due to heavy cost overruns. The first production unit, for pharmaceuticals, including folic acid, went into operation on November 25, 1947, and the second, for iron blue pigment, used in printing inks and surface coatings, in February 1948.[31] Staff transfers from Bound Brook to the new facility included James Bourland, who became chief chemist in the pharmaceutical section, and Harold Lacey, who was appointed senior chemist. The third unit, for melamine production, was completed in the fall of 1948. Apart from special low-volume products, amino-resin manufacture ceased at Bound Brook around 1950. However, rubber-processing chemicals continued to be produced mainly at Bound Brook, although a few items were manufactured at Warners.[32]

The increasing use of resin textile finishes, including those based on Calco melamine Aerotex Resin M-3, Aerotex Cream 450, and combinations of resins with copper, led to the introduction of the Calcodur resin-fast direct dyes. These dyes were developed so as to remain fast after the fabric was finished with a resin treatment.[33]

In 1950, the Calco Chemical Division comprised seven main factories, three in New Jersey (Bound Brook, Warners, and Newark), one in Ohio (Marietta), two in Virginia (Damascus and Piney River), and part of the new Willow Island facility. Damascus specialized in sulfur dyes for cotton yard goods and alizarin red for printing inks. The Marietta facility had until 1946 been the Marietta Division of the American Home Products Corporation. It produced intermediates, dyes, and DDT. In August 1945, the Calco Chemical Division had acquired the titanium dioxide factory of Sherwin-Williams at Gloucester City, New Jersey. At first it was managed by Ames B. Hettrick, of the Piney River facility. Hettrick was an assistant manager in the Calco Pigments Department, who in 1947 was appointed assistant manager of manufacturing at Bound Brook. In 1953, a third titanium dioxide facility, at Savannah, Georgia, was added to Calco, from which time Gloucester City was run down. At the same time, American Cyanamid introduced its Unitane range of titanium dioxide white pigments. Organic pigments, including phthalocyanine and azo colorants, were made for the Calco Pigments Department at Bound Brook and Newark.

During the Korean War (1950–53), infrared absorbing dyes were developed for the U.S. government. While some were delivered in 1952, the research work was difficult, and not completed successfully until after the end of hostilities. The challenge was based on the fact that the fast vat dyes used in military uniforms showed high infrared reflectance. While the dull, drab shades made soldiers relatively poor targets under visible light, infrared-observation with snooperscopes and sniperscopes enabled their easy detection, since they stood out against the average terrain. Von recounts that the "infrared absorbing dyes were vats, so they were developed by our plant technical group. The idea was to form dyes that had the same absorption characteristics as the vegetation background. This would foil the enemy's use of infrared snooperscopes at night and thus provide camouflage. We did not develop these dyes soon enough to be used in Korea, but they were used in dyeing uniforms for Vietnam [from 1964]." The military vat dyes, with low infrared reflectance, but retaining fastness to light and washing, incorporated what was referred to as the "benzanthrone acridine ring."[34] Also in 1952, American Cyanamid introduced what was probably the first material for use in disposable paper clothing, and its Explosives Division (New Castle and Latrobe, Pennsylvania) was merged into Calco. In 1953, Calco acquired additional manufacturing facilities for textile resins at Charlotte, North Carolina. At that time, Calco, DuPont, and the National Aniline Division of Allied Chemical & Dye produced over 60 percent of dyes made in America, with a further 20 percent made at GAF and the Cincinnati Chemical Works.

Isaiah Von provides a useful explanation of abbreviations in use around 1950 for the Bound Brook departments:

At this time, Bound Brook consisted of various departments, which apart from two were each represented by a letter. A was mainly the beta-naphthol shop; E, F, G, and H all made dyes. Department E covered azo and triphenylmethane dyes, F-B incorporated the lake shop, the laundry blue shop, and the Tobias acid shop; G was devoted largely to vat dyes and their intermediates, and H included the sulfur and stilbene shop; I, This department made sulfuric and nitric acids and perhaps smaller amounts of other inorganics; N, This department contained stills and originally fractionated coal tar. When gas became the main feedstock, the stills were used mainly for solvent recovery; P, Pharmaceuticals Department; R, Rubber Chemicals. Each lettered department

Organization of Calco Chemical Division Manufacturing and Service Departments in November 1953[35]

Plant manager: Bound Brook, N. N. Gaboury
Assistant plant manager: F. B. Manker
Manager of manufacturing: V. E. Atkins
Production manager, Dyes Departments (E, F-B, G, and H): G. W. Hedden
Department E
General superintendent: Hugo Kladivko
Department F-B
General superintendent: D. de Rosset (east half building 62; building 42 lake and laundry blue shops; Tobias acid shop in building 61; and building 12)
Department G
General superintendent: R. B. Latimer (building 42, vat and blending; buildings 82, 83, 94, 97, 103; and CS&B [Color Standardization and Blending] shop, in building 38)
Department H
Kladivko in charge of Department H-1 (including the stilbene shop, in building 41); de Rosset in charge of Department H-2 (buildings 19 and 66, the sulfur color shop)
Application Laboratories
In charge: E. Wirth
Intermediates and Chemicals Departments, A, I, N, P, and R
Production manager: W. T. Ries
Maintenance and Construction Departments[36]
General superintendent: Stuart Whitehead
Stores Department
General superintendent: H. J. Wells
Power Department
Manager: William Rohrhurst
Plant Protection Department
Superintendent: M. D. Clark
Production Control Laboratories
Superintendent: H. J. Rodenberger
Effluent Problems and Information
Coordinator: D. M. Aumack

This list is based on the final reorganization of the Calco Chemical Division, as from November 17, 1953.

was managed by a general superintendent, and had a chief chemist and a chief engineer. Each numbered building had a superintendent with two to four general day foremen working for him. The plant was further organized like this: Intermediates Departments, A, I and N; Dyes Departments, E, F, G and H; Pharmaceuticals Department, P; Rubber Chemicals Department, R; the Organic Pigments Department; and the Plastics Department ... Each of these 6 departments was headed by a manufacturing manager who reported to the plant manager.

V. E. Atkins was the Calco works manager from February 1945 until May 1947, when he was appointed manager of manufacturing. Reporting to Atkins from 1947 was the plant production manager, a new post first occupied by L. M. Phelps, and then by Louis Robins. Robins occupied another new post, the plant manager, covering production, utilities and services, during 1952–53. Robins's successor was N. N. Gaboury. The plant manager at Charlotte was G. W. Mason; the general superintendent at Damascus was E. F. Akers. D. M. Aumack was named manager of the Bound Brook effluent plant, as well as of similar facilities at other Calco sites, early in 1948. The new layers of middle management would be kept in place for the following three decades.

Cost Statements

Profitability required careful attention to cost considerations. This applied to technical staff as well as to accountants. Men like King who had made their livings in industrial environments and had started their own enterprises before joining Bound Brook understood the implications fully. It was necessary to explain technical matters, such as mass balance, in terms that could be readily understood by accountants, and conversely, accounting procedures that could be understood by those engaged in manufacturing. Using examples of Bound Brook products, King, in his role as manager of technology, placed great emphasis on the importance of cost statements to the technical departments, since these statements indicated where to minimize losses and maximize recovery of solvents and of chemicals that did not participate in reactions but that were necessary for their successful outcomes. This included methanol and ammonia for amino resins, and the expensive solvent pyridine.

For this reason we like to see such materials shown as gross usage, recovered and net usage; the usage of methyl alcohol and ammonia in melamine is a case in point. The losses of these accessory materials can exert a significant influence upon the cost of manufacture of melamine quite aside from questions of yield or output. The usage of pyridine in sulfa drugs and vats is another example and in this case a special cost statement is made for this particular purpose. Not until this was done did we begin to get the losses of pyridine down to amounts that may well be the envy of competitors. Although a brilliant process for the recovery, purification and dehydration of pyridine was developed by our technical department, not until we had an accounting statement that clearly and quickly enabled us to see where losses were occurring, whether in Departments P, N, or G, was it possible to handle commercially as much as five million lbs. in a year's time of this scarce and costly commodity with a loss of less than 6% over all the operations in Departments P, N, and G. This, I think, is one of the outstanding examples of the direct effect of a good cost statement on profits, and accounting and technical people came together on a strong bridge of understanding and common need to produce this.[37]

Thus, notwithstanding the fact that the recovery process for pyridine based on Carl Mensing's work was of tremendous technical importance, it was the cost statements that identified in which departments and processes the major losses were occurring, and led to efforts aimed at minimizing these losses. There was also the need for careful and precise control of chemical processes. As an example, King discussed the benzidine-derived trisazo dye Direct Black. Its manufacture involved three separate coupling reactions:

A typical example of the necessity of constant and precise control in the dyestuff producing division at Calco may be shown by the progressive damage its lack could cause in the manufacture of Direct Black, a common azo dyestuff. Direct Black is made out of benzidine, H-acid, aniline, and metaphenylenediamine. If the benzidine is not quite completely diazotized at both ends, then there is a foreign dyestuff formed that may not be completely removed. If the coupling with H-acid is incomplete or imperfectly balanced to a precise nicety, then either the excess H-acid or the excess benzidine may each form different and separate dyestuffs in the next operation in which the diazotized aniline is coupled on to the benzidine-H-acid combination. If the coupling of aniline is not balanced equally precisely then any excess of it can produce other dyestuffs in the next operation, the coupling with metaphenylenediamine. At least four, and possibly six, separate impurities can be produced by faulty balancing of control in this one simple process alone. Their formation must either be prevented or such impurities must be removed, which calls for another control, in order to have a satisfactory manufacturing process for this particular dyestuff.[38]

In the early 1950s, Isaiah Von, who endorsed King's strong emphasis on cost statements and cost accounting in general as a means of increasing labor efficiency and productivity, found the system of internal costing adequate, even though it was far from perfect, especially when compared with similar arrangements at DuPont.

Cyanamid transferred products at cost from division to division and from department to department within a division. DuPont, on the other hand, made such transfers at a negotiated price which would allow some profit to be shown by the transferring department. This gave the latter an incentive to operate at top efficiency and to do cost reduction work on the process. The "negotiated price" would be somewhere near the middle between the manufacturing cost and the market price.

When I first went into the plant in 1953, cost accounting was carried out by a number of clerks in each building who would keep track of the weights of the raw materials used and the yields obtained and also the amount of labor devoted to each product. All other costs, such as power, steam, plant services, such as transportation, general maintenance, building and equipment investment, etc., were lumped into [the] overhead which was added to product cost as a ratio of labor used. Although not perfect, this gave a pretty good indication of the relative costs of the products. A further feature of the system was that a record was kept of the best yield performance for each product and it served as a goal to be met. The only way this BPP [Best Past Performance] could be lowered was to convince a member of the plant manager's staff, who required a lot of convincing. Cost reports were issued quarterly and the main fault that was found with these was that the costs varied considerably from quarter to quarter because of changes in product mix and volumes.

After the 1950s, however, this system underwent considerable reform, became inflexible, and was incapable of taking into account fluctuations in demand during an accounting period, as described in the next chapter.

Instrumentation

Less problematic was the introduction of new instruments into laboratory and production processes, and for use in dye matching and standardization. For the latter, the traditional colorist in the dye industry had worked within the parameters of shade, strength, and brightness. Through experience, he managed to juxtapose physiological and aesthetic considerations with visual sensations to match colors to a remarkably high degree of accuracy. Often he could detect deviations that were virtually imperceptible to the untrained human eye. The color physicist, by contrast, worked with electromagnetic energy, and recorded frequency and intensity using the combination of diffracting prisms, collimators, and slits, and detectors, signal amplifiers, and other electronic components that constituted the spectrophotometer. The result, for a given color, was the characteristic spectral curve. From the late 1940s the colorist had to adjust to the new instrumental way of seeing color.[39] This was successfully achieved in the dye industry because the proponents of the new methods were themselves within the industry, mainly at American Cyanamid. They could easily relate to the specific requirements of colorists and scientists working on problem solving in testing, service and inspection departments, and to the needs for dependability and uniformity in the supply of colorants.

The first commercial recording spectrophotometer was a prototype constructed in 1933 by General Electric and installed at the International Printing Ink Corporation, in New York. It was based on the "recording photoelectric color analyzer" (1929) of MIT professor Arthur Hardy; its success led General Electric to make the instrument more widely available, at first through the construction of seven instruments, all placed in commercial service during 1933. The General Electric instrument became generally available in 1935.[40] Calco acquired a General Electric Hardy recording spectrophotometer, which from 1935 was modified by Pineo for use in color analysis. The spectrophotometer, later more generally known as the spectrometer, measured relative amounts of radiant energy as a function of wavelength, and differed from the photometer employed in colorimetry since it used continuously variable monochromatic bands of energy. Hardy made further improvements, including incorporation of a polarizing photometer and an integrating sphere. In 1937, Hardy suggested, in *American Dyestuff Reporter*, the applicability of the spectrophotometer to color problems in the textile industry. During 1938–40, Pineo filed patents for spectrophotometers and methods of spectrophotometric analysis and prediction. He developed the R cam, which plots the so-called Kubelka–Munk function (P. Kubelka and F. Munk, 1931), enabling rapid quantitative determination of colorant, and facilitating color matching and comparison of dye strengths.[41]

These developments enabled Royer, Stearns, and colleagues at Calco to advance instrumental applications based on the absorption and reflectance of light.[42] As a result, standardization of dyes and pigments moved from instrumental colorimetry to spectrophotometry at Calco in the 1940s after Stearns demonstrated the overwhelming superiority of the latter. In 1944, Stearns and Eugene M. Allan achieved the first-ever color match using instrumental data. In the same year there were four Calco technical bulletins dealing with these instrumental applications, two authored by Stearns and two coauthored by Stearns, one with E. Abbott and the other with F. Noechel.

Conversion of instrumental data from the spectrophotometer to tristimulus values and then to units of color measurement was, however, a lengthy process, involving correction, tabulation, and computation. This restricted the use of the General Electric instrument in the control of blending until 1949, when the automatic tristimulus integrator became available. The integrator was developed at GAF by Hugh R. Davidson, drawing on the studies of other investigators then at GAF, including two outstanding leaders in color technology, Henry Hemmindinger and I(saac) H(ahn) Godlove.[43] The integrator, an electronically-controlled ball and disc device, was designed for use with the General Electric spectrophotometer, and enabled measurement and analysis of color within two-and-a-half minutes. The GAF commercial instrument was known as the General

Aniline–Librascope tristimulus integrator. It was described for instrument specialists by Davidson and L. W. Imm in *Journal of the Optical Society of America* in 1949, and for color users by Davidson and Godlove in the *American Dyestuff Reporter* in 1950. Previously, as Stearns later observed, dyes were blended to shade with tristimulus values (based on three color values) measured with a colorimeter, something that could not be achieved in everyday practice with the spectrophotometer. Stearns recalled: "When we started to use the spectrophotometer for blend control, we corrected shade at specific wavelengths in accordance with standard analytical procedures for multicomponent analyses. We could not use tristimulus values from spectrophotometric data because of the long time required to calculate them. The Librascope integrator was not available until 1949. For a while we compared the colorimeter blending method with the spectrophotometer by running parallel tests."[44]

In 1947, Kienle and Stearns had described twenty-three modifications of the Hardy recording spectrophotometer that were applicable to the dyer and textile user. Stearns and colleagues designed various attachments for the Hardy instrument that enhanced its value to the dyer.[45] This explains why, for reflectance studies, the General Electric spectrophotometer was the most popular, more so than Beckman instruments that were fitted with reflectance attachments. A new General Electric model, offering advantages of speed and high signal-to-noise ratio, was introduced in 1955. By then, Bound Brook had contributed to standardization of the method for computing results from instrumental data—conversion to tristimulus values, etc.—through its IBM automatic computation service.

Stearns's work represented the most successful use in industry of instrumental-monitored blending, and of spectrophotometric curves for routine, reliable identification of aromatic molecules. This placed American Cyanamid at the forefront of spectrophotometry. Above all, it was Stearns who had most successfully applied optical and color theory to spectrophotometric data, colorimetric measurements, and calculations of dye-bath formulas. He also employed the spectrophotometer in quantitative measurements of a two-component system of reflectance measurements, such as metal-dye complex formation within the fiber.

R. Bowling Barnes at the Stamford laboratories also made notable advances in instrumental analysis. Significantly, the first factory of Perkin-Elmer, founded by Richard S. Perkin and Charles W. Elmer in 1938 to manufacture advanced optical systems, was almost adjacent to the Stamford laboratories, and publications by American Cyanamid scientists acknowledged contributions from Perkin-Elmer. The outcome was that the practical application of spectrophotometry was advanced more by American Cyanamid scientists Stearns and Barnes than in any academic laboratory.[46] As for the wider usefulness of laboratory instrumentation, this required commonly accepted norms of measurement and interpretation, an area in which Calco and other American Cyanamid scientists contributed toward technical standardization in both industrial and academic communities. Barnes and Stearns had been present at the October 1943 meeting of the Optical Society of America, held in Pittsburgh, on which occasion the role of the National Bureau of Standards in color measurement was emphasized, and subsequently were among the principal participants in the development and use of spectrophotometers. Barnes, then director of the Physics Division at Stamford, served as a civilian with the Manhattan Project.

In 1945, Barnes and colleagues, jointly with Richard F. Kinnaird of Perkin-Elmer, for the first time described the latter firm's model 12 infrared spectrophotometer.[47] During 1945–46, "Barnes and his coworkers published two papers in America which were to have a profound effect on the design of flame photometers."[48] Like the instruments they were describing, the American Cyanamid authors used precision and simplicity in both their reports and their gatherings with other scientists, which did much to bring instrumentation into introductory courses in chemistry. While Stamford was associated mainly with developments in infrared (IR) spectrophotometry, Bound Brook's main contribution was to the more sensitive ultraviolet (UV) spectrophotometry, in addition to work in the visible region. The latter offered more accuracy and precision than IR for quantitative chemical analysis. They contributed to widely adopted routine methods for qualitative and quantitative chemical analysis.[49] To this day, Stearns's *The Practice of Absorption Spectrophotometry* remains recommended reading for students.[50]

Robert C. Hirt was another notable American Cyanamid contributor at Stamford. With colleagues, he modified UV spectrophotometers, namely the Beckman DU and a Cary machine, for more direct use in identifying individual substances.[51] The publications of Stamford scientists included accounts of instrumental analysis of chemicals in the industrial environment. Thus they analyzed two-component mixtures that included nitrobenzene and aniline, "a combination which had been of interest in an industrial hygiene investigation," and that were characteristic of dye manufacture, which in the case of American Cyanamid meant Bound Brook. Details of this absorbance-ratio method were presented at the 4th Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy held in March 1953.[52]

The benefit of novel instrumental applications at, and databanks held within, a central research laboratory, such as American Cyanamid Stamford, was that important and accurate information could be rapidly transmitted to other company-owned sites: "This allows a laboratory with a large library of spectra to transmit a minimum of information—by telephone, for example—to a smaller laboratory or plant control unit to enable it to set up and use a plot of absorbance ratio *vs.* relative concentration."[53]

There were numerous other applications of instruments at Bound Brook. Royer undertook microscopic studies on wool dyeing with Millson and M. E. Wissemann before 1940, and, as indicated in a number of technical bulletins, during the 1940s on wool, nylon, leather, and other dyeings, in collaboration with Amick, Louis I. Fidell, Anna Harding, Maresh, McCleary, T. E. Nestler, Stearns, and Willard H. Watkins. In 1946, Royer, Kienle, and McCleary were involved in the development of the dyeometer, which permitted photometric measurement of the strength of the dye bath during dyeing. Further progress with this instrument was made with O. W. Clark and J. M. A. de Bruyne (Ph.D., Duke University, 1932), who joined Bound Brook in 1946.[54] Henry Millson invented the microdyescope, a tool for observing the behavior of textile fibers as they took up dyes. It was used with a recording spectrophotometer to monitor vat dyeing by Clark and Zimmerman.

Royer's achievements led to his promotion as assistant director of the Bound Brook Application Research Department. In 1946, he was awarded a fellowship in biological photography by the Biological Photographers' Association, and four years later received the prestigious Olney Medal of the American Association of Textile Chemists and Colorists (named in honor of Dr. Louis A. Olney). In 1950, Royer was chairman of the North Jersey Section of the American Chemical Society. Millson, for his invention of the microdyescope, was recipient of the Olney Medal in 1958. In 1979, Millson and the American Association of Textile Chemists and Colorists established the Henry E. Millson Award for Invention that recognizes achievements in textile wet processing. Roy Kienle, expert in surface coatings, in addition to resins and processes of coloration, in 1949 gave the first Mattiello Lecture (named in honor of the late Joseph J. Mattiello) before the New York Paint and Varnish Production Club. The topic was physical chemical research in the protective coatings industry, an area where Bound Brook chemists, physicists, and technical people had considerable expertise.[55] They were a mix of rubber and textile experts, plastics engineers, and coatings specialists who would only later become collectively known as polymer scientists. In 1955, the club awarded Kienle its PaVaC (Paint and Varnish Club) Award, and in 1960, the year in which the name of the club was changed to the New York Society for Paint Technology, created the Roy H. Kienle Award in recognition of technical achievement and outstanding service to its technical committee.[56]

The variety of types and applications of instruments, particularly those employed in process control, had by the early 1940s made necessary the establishment of another department at Bound Brook:

> Control involves also the use of instruments ... We employ nearly 10,000 separate ones varying from simple measuring sticks to complicated control devices of all kinds, and we have over a quarter of a million dollars invested in them. We tell our young engineers that they will sooner or later encounter our specialist on this subject, and not to tie a string to a bottle to get a sample out of a tank, but to use the proper sampler made by the Instrument Department and approved by the corresponding Technical Committees.[57]

The New Pilot Plant and Naphthalene Still

Calco's principal assets were its proprietary information and patents, the outcomes of its own research and development, as well as of technology licensing agreements. The conversion of research and development into useful technology relied on the availability of modern small-scale manufacturing facilities, as found in the pilot-plant building constructed in 1945, though it "was outgrown in about six years' time." In 1952, it was replaced by a new Central Pilot Plant, having a floor area of about 11,000 square feet; it served as a preparations laboratory, a site for use and development of pilot-plant and unit-operations equipment, and also for corrosion tests.

Operation of the first [1945] building had indicated a considerable number of improvements that would add to the flexibility of the over-all pilot plant operations ... With the upper floor at the 20-foot level, it is possible to have three levels of processing equipment with adequate headroom at each level ... Most drowning tanks and secondary reactors are located at the 10-foot level under the main reaction vessels. In the open area below the top floor it is possible to make temporary installations of auxiliary tanks and special isolation equipment–e.g. different types of filters and centrifuges–as required by the particular process.[58]

In the winter of 1953, no. 6 naphthalene still, a 123-foot-high semi-refining column, was installed in the southwest of the manufacturing area. Occasionally, and especially after coal-tar distillation ceased in the 1960s, this and other distillation columns found alternative uses, particularly in the recovery of valuable solvents. Vanderwaart tells an amusing story connected to the use of the columns for solvent recovery:

The light oil distillation columns were being used to recover ethyl alcohol, the product was run to a tank car on a siding. As coal-burning locomotives made regular use of the adjacent track, the tank car was purged with carbon dioxide. To be sure that the car was completely purged, the carbon dioxide line was led to the bottom of the car. This was the situation when the federal alcohol inspector came by. He stormed into Brad Manker's office in Bldg 106-2 and spoke out in a loud voice, "Do you know what you are doing out there?" Brad replied that of course he knew and that they were recovering alcohol. The inspector demurred. "You are not recovering alcohol. You are bubbling carbon dioxide through alcohol. You are making champagne and the tax on champagne is–!!!"[59]

To enhance new strategies in product development a Market

Research and Development Department was created in 1953, headed by Alden R. Loosli (previously, from 1947, assistant sales manager, Rubber Chemicals Department). At the end of the year, American Cyanamid announced the demise of the Calco Chemical Division and the establishment, in its place, of the Organic Chemicals Division, with a newly created General Staff, for overseeing this and other divisions, new and old. It would be the third and final corporate name change for the Bound Brook dye-making and chemical facility.

Section 3

The Organic Chemicals Division at Bound Brook: 1954–1982

Chapter 6

Corporate Reorganization

"A new era for Bound Brook began on January 1, 1954. On that day, far reaching changes were made in the organization of Cyanamid because of the rapid growth experienced by the company."—*Cyanamid Organic Chemicals Division. Bound Brook Plant 50, 1915–1965* (Bound Brook: American Cyanamid Company, 1965), 36.

In the early 1950s, the proliferation of types of products that American Cyanamid's Calco Chemical and other divisions manufactured and handled, and the different sectors that they served, encouraged the corporation to embark on a major restructuring exercise, one that paralleled similar organizational changes elsewhere in the chemical industry in the face of shifting market climates. This represented not only the corporation's new management commitment, but also the urgent need to bring into line what Gerard (Jerry) A. Forlenza, who headed various divisions in the 1970s, calls certain "powerful fiefdoms" and the individuals who ran them. The principal architect of the change that was to completely alter the culture and management styles of the corporation was its president, Kenneth C. Towe. Changes also took place at the corporation's highest management levels, including the separation of executive functions from immediate divisional responsibilities. The outcome was that on January 1, 1954, American Cyanamid inaugurated what it called the General Staff—the senior corporate, or executive, staff policy group—and reorganized all its operations into a new grouping of main corporate divisions.

There were four newly created divisions, of which one, the Organic Chemicals Division (OCD), was built around the "nucleus of the now extinct Calco Chemical." While the Calco name went "out of style," it was retained as a trademark for those products most closely connected with Bound Brook, the dyestuffs. The OCD comprised eight facilities, of which Bound Brook was the largest. It was the "the big division," associated with scientific and technical progress and a high return on investments, of which it was soon said, "When it developed something you could count on it."[1]

The other new divisions, all of whose activities overlapped with Bound Brook, were Research (Bound Brook research laboratories were assigned to the Research Division), Fine Chemicals, and Pigments. Each manufacturing department had its management team and production, application technology, and marketing departments, and operated as a separate profit center. The creation of the new divisions was accompanied by a number of changes in management and research personnel, that in certain cases meant transfer away from Bound Brook to New York and elsewhere.

Calco general manager Sidney C. Moody (1945–53) was elevated to the General Staff. He was associated with the development at Bound Brook of a new continuous, semiautomatic diphenylamine (DPA) plant—heating aniline in the vapor phase under pressure in the presence of a catalyst in a corrosion-resistant autoclave—described by Garrett Hill as "unsurpassed in simplicity of design and operation."[2] A. R. Loosli, until 1954 assistant general manager, was appointed assistant general manager of the Fine Chemicals Division in New York. Kenneth H. Klipstein became general manager of the Research Division, also in New York. (He was involved in research management until June 23, 1965). In 1955, George Royer was appointed Klipstein's administrative assistant at Stamford, where he co-ordinated budget, personnel and publication policies for the Stamford, Bound Brook, and Pearl River (Lederle) research laboratories. In the 1960s, Royer's title was administrative director of the Stamford laboratories. John Allegaert, manager of the Calco Pigment Sales Department, became general manager of the Pigments Division, of which the organic pigments section operated at Bound Brook. In 1965, he would be appointed president of American Cyanamid. Robert Parker, who with Mario Scalera had been at the same level as assistants under Lecher, and had headed the Bound Brook Research Department, left in August 1954 to become Lederle's director of research. Parker's successor as director of the Bound Brook Research Division's laboratories was Dr. Joseph Hayes Paden, a physical chemist transferred from Stamford.[3] In 1956, Scalera, by then the OCD director of research for dyes, pigments and intermediates, moved to the Agricultural Division. Stearns became assistant manager of Midwest territory, operating out of the Chicago office. Another move was the transfer to New York from Willow Island of James Bourland, who became technical director. Isaiah Von observed that these "were the last group of changes using veterans of Calco and the dyes business. Beginning at that time, they started bringing in outsiders with little or no experience into OCD management."

This also marked the changeover in control of R&D strategies from scientists close to the bench to marketing departments and their managers, a number of whom did have technical backgrounds. It coincided with the general growth of what Erwin Klingsberg calls the science of management, generally known as research management, ostensibly the discipline that would erase the frictions between science and industry. It was part of a prevailing business school philosophy—in part drawing on prewar American-style scientific management—that was impacting on the operations of many major corporations. New terms were introduced, such as management science and systems analysis, which both meant operations research, the scientific approach to making decisions. These changes were inspired by outspoken and respected critics of corporate management, such as Vannevar Bush, who had introduced operations research—originally developed in Great Britain—into the U.S. military in 1942. In Klingsberg's view, however, the main change at Bound Brook was that accountants and marketing men took over. No doubt American Cyanamid did need to focus on new marketing strategies, but there were to be many mistakes during the 1960s—often resulting from ill-advised recommendations by market analysts and a changed business mentality—that had adverse impacts on American Cyanamid and other chemical corporations.

At the time of the reorganization, Victor King compared, from his perspective, the prospects for American chemical industry with those of Europe, where, in his view, strategic alliances and mergers facilitated protectionism, created monopolies, and held back innovation: "In Germany, where there was practically no war damage to the chemical industry (Ludwigshafen–Oppau suffered two disastrous explosions, which had nothing to do with the war), and where the I.G. was not de-cartelized [until 1952], and in France and Italy, tho they did suffer considerable war damage, various companies have been combined into fewer, stronger ones, so that we may expect a continuation of the policy (very different from ours) of stifling rather than accepting the challenge of competition."[4] King also emphasized the higher wages of American workers, giving them more power as consumers, which in turn enabled ongoing expansion of the economy. And, of course, he did not mention that price-fixing arrangements were not unknown among large American firms, including American Cyanamid, nor the importance of trans-Atlantic strategic licensing agreements. What is remarkable, however, is that in the long run practically all major American and European chemical firms did combine into "fewer, stronger ones," particularly in the 1990s.

American Cyanamid's "Big Division"

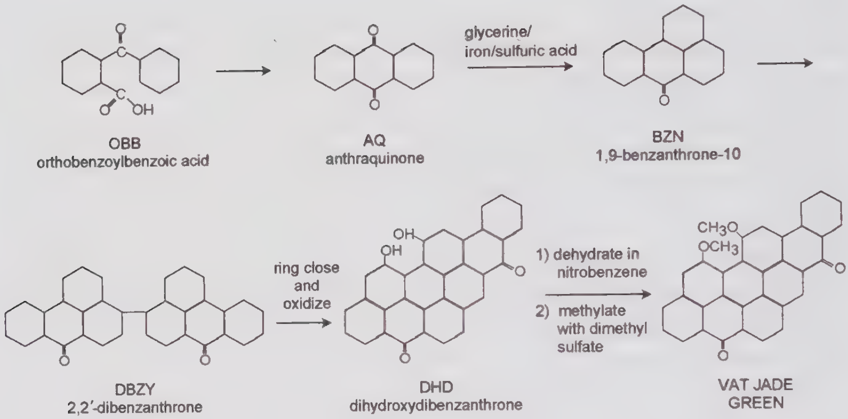
L. C. Duncan followed Moody as general manager of the OCD, during 1954–55, and was succeeded by V. E. Atkins, who served for two years, 1955–57.[5] Shortly after Atkins took over, a major expansion at Bound Brook, including of laboratory facilities on the Hill Property, was announced.[6] Production of bulk pharmaceuticals, including sulfa drugs and pharmaceutical pigments, was now shared between Bound Brook and Willow Island. The proliferation of departments included the Household Products Department that at Bound Brook produced a packaged laundry blueing called Bleachette. The Plastics and Resins Division, active in part of the Bound Brook factory for a number of years, also contributed to the variety of products and increased output. The Calco Explosives Division became the OCD Explosives and Mining Chemicals Department. As a highly diversified corporation, American Cyanamid was well-placed to find new markets for its products, particularly in the textile and allied industries. There was also the challenge of new intermediate and dye processes.

About half of all new process investigations were those carried out under the supervision of technical director Garrett Hill. His staff of almost forty included personnel from Departments A, I, P, R, and N, and the pilot plant. Hill's assistant during 1954–55 was Verner Alexanderson, who had received his bachelor's degree, majoring in chemistry, from Amherst in 1938, and then spent one year at Harvard Business School. He joined the Warners facility in 1939. During 1940–54, he was with the Technical Department in New York. Alexanderson's later posts at Bound Brook included technical manager for, successively, intermediates, pharmaceuticals, and rubber chemicals, and senior management analyst with the Commercial Development Department. During the mid-1960s he proposed that aniline production should be moved to Houston and all bulk manufacture to other sites, in part to overcome effluent problems and the limitations of the power plant, but also in order that Bound Brook could specialize in pharmaceuticals and other fine chemicals.

Elsewhere at Bound Brook technical investigations and research were also carried out for new dye processes. In 1956, Isaiah Von was appointed chief chemist in Department G, where he supervised production of vat dyes and miscellaneous intermediates. In the same year, based on his innovations, Bound Brook introduced its last major vat-dye process, an improved route to Jade Green. By this time, relates Von,

> the Research Department was no longer involved in vats. The technical work was done in my Plant Technical Group, which reported to the Production Department. In fact, I was the one who worked out our process. Of course I borrowed a little here and there. By then there were 6 or 7 industrial processes available in the literature. I picked and chose but added some novel features of my own, which resulted in the cheapest and best process around (if I say so myself). This process was operated unchanged until the end. From about 1974 on, Calco was the sole source of Jade Green in the U.S. The greatest effort of my group was on cost reduction. This became essential because about 1952 a severe price war broke out after a Pittsburgh chemical business decided to enter the fine chemicals business and chose vats as the starting point. Since they could not provide the technical application service that the established companies could they decided to get market share by cutting prices. I remember that when I started to work on Jade Green the selling price was $2.25/lb. By the time I finished the price was $1.25 and … for a short while DuPont was selling it at $1.00. There was similar price cutting on other major dyes.

A novel Bound Brook gray vat dye became a long-term best seller and substantial contributor to corporate profits.



1958	building 82	building 83	building 83
1979	building 103	building 103	building 103

(original process dates from 1920)

Vat Jade Green (Bound Brook abbreviations)

Very few new vats were developed by 1958, when [the research for vats] was shut down ... Perhaps the most important new dye that was discovered [at Bound Brook] was Vat Gray 2G [also GG], during an effort to cheapen Vat Olive Green B. This was a very pleasing gray and caught on in the industry in a big way. Later, when I was chief chemist, using Klingsberg's analytical chromatographic method we found that it was a mixture of Vat Olive Green B, Vat Olive T and a dibenzanthrone. During the price wars of the fifties, while vat dye prices such as Olive Green B hit rock bottom, Vat Gray 2G sold at its full price. In one year Vat Gray 2G provided half the profit of the vat department.[7]

Von recalls how problems between manufacturing sections at the Bound Brook site had to be resolved between divisional heads at the New York head office, much to the annoyance of factory personnel, particularly as the organizational arrangements were not always consistent.

For many years, the Plastics and Resins Division (not connected with OCD) maintained a manufacturing building (Bldg. 85) right in the middle of the

Bound Brook plant, whose manager reported directly to a superior in NYC. When our Bldg. 83 which was alongside and housed processes for vats that used some very strong reagents would accidentally let loose one of these strong chemicals, the plastics manager called his boss in New York to complain. The latter would cross the hall and talk to his OCD counterpart, who would then call Bound Brook. As you can imagine this angered the Bound Brook plant people very much. About 5 years before Bound Brook closed there was another one of those reorganizations and Bldg. 85 came under Bound Brook manufacturing management at which time they got their revenge. The Plastics Manager lasted only about 3 months.

One notable area of novel Bound Brook pigment technology until the mid-1950s, as both Erwin Klingsberg and Isaiah Von agree, was the development of novel modifications of phthalocyanines. Dr. Theodore F. Cooke Jr., for example, undertook useful investigations into stabilization of copper phthalocyanines. However, Klingsberg and Von emphasize how poorly this and similar work was exploited, at great commercial cost. Von recalls:

Perhaps the most useful invention resulting from Calco research, at least in the color area, was the development of Green Shade Phthalocyanine Blue. Phthalocyanine Blue pigment comes in two major crystalline forms, referred to as red shade and green shade. Red Shade was developed first and for over ten years was the only Blue on the market. Red Shade was easy to make but was unstable. Calco investigated the Green Shade which is stable and learned how to put it into pigmentary form, and then set about demonstrating its usefulness as a pigment. Today [2001] Phthalocyanine Blue is by far the largest volume organic colorant in use and the Green Shade is about 90% of the total. The irony is that the Pigments Division, with J. Allegaert as General Manager, refused to support this project and Calco lost its potential lead to DuPont and others.[8]

The other firms included GAF, that invested much effort into moving beyond the shades of blue.

The production of organic pigments at Bound Brook was actually managed more by the OCD than by the Pigments Division, that had taken over responsibility for inorganic pigments from the Calco Chemical Division. Production facilities for the new Pigments Division consisted of two titanium dioxide plants (Piney River, Virginia, and Savannah, Georgia), the inorganic pigment unit at Willow Island, and "manufacturing facilities for organic pigments at Bound Brook, Bldg. 86 and part of two other buildings. The latter were taken out of dyes manufacturing and a new pigments manufacturing department [sometimes called the Organic Pigments Department] was formed that reported directly to the Bound Brook plant and only indirectly to the Pigments Division." Thus when Von was appointed chief chemist of the Pigments Division at Bound Brook in 1965 (a post he retained until 1981), "I really had two masters."

Well before the many organizational changes, American Cyanamid's dye and textile research was responding to the different needs of its customers. The Application Laboratory on the Hill Property had came up with a number of useful innovations. For example, in 1956, a novel technique for producing colored patterns on cloth, known as emulsion printing, was developed by Fred Fordemwalt, A. F. Klein, R. D. Greene, E. F. Scott, and J. L. Borstelmann.[9]

During the 1956 centenary celebrations for the discovery of mauve by William Perkin, ICI in England announced the introduction of the first fiber-reactive dyes for cotton, in which the dyes were—for the first time ever—chemically bound to fabric. This would have a great impact on future research into dyes. Meanwhile, to mark the historic moment, the Color Association of the United States, Inc., promoted three variants on the original 1856 color, called Perkin Mauve, Perkin Lilac, and Perkin Orchid. The main American celebratory event was organized by the American Association of Textile Chemists and Colorists and held at New York's Waldorf Astoria Hotel during one week in September. Edwin Stearns represented the Optical Society of America and the Inter-Society Color Council, Eugene Allen the National Paint, Varnish and Lacquer Association, Inc., August Merz the Synthetic Organic Chemicals Manufacturers' Association, and W. H. Peacock the Society of Plastics Industry, Inc. Bound Brook scientists presented historical surveys of dye invention and accounts of more recent work, including color measurement.[10]

Lecher, as pointed out earlier, delineated in some detail the development of early synthetic dyes. Fordemwalt described the history of fast dyes. Kenneth H. Klipstein, who had worked on the application of a mono-azo dye that changed the color of Florida oranges to orange from a natural greenish tint (due to chlorophyll in the skins), explained that trials commenced in 1934, after which Calco's FD&C [Food, Drug and Cosmetic] Orange no. 2 was used from 1935 to 1939. During 1938–39 the dye subsequently known as FD&C Red no. 32, and later External D&C Red no. 14, was introduced for this purpose. The latter was an azo compound made by the coupling of beta-naphthol to the diazonium intermediate produced from 2,4-dimethylaniline (an isomer of xylidine). It's use was authorized by the Haley Act until March 1, 1959. However, not long after 1956, a group of children at a Halloween party became sick from eating candies colored with the dye. A new dye was sought, and in 1959, Bound Brook chemist Robert Long developed the methoxyaniline analog known as Citrus Red 2, which replaced D&C Red no. 14.[11] In the mid-1950s, eighteen synthetic dyes were permitted in foods, though others were permitted in drugs and cosmetics. The number has since been reduced to nine certified colors, including Citrus Red 2, which is restricted to orange skins.

While the Perkin centenary events were in progress, a new research building, no. 4, close to building no. 3, was under construction on the Hill Property. Completion was planned to coincide with the year in which American Cyanamid marked, with considerable optimism for the future, its 50th anniversary.[12] Jay Leavitt was responsible for the design of the building, and the dedication took place on schedule in 1957. At first there were two wings, A and B, in which most of the Chemical Research Department was installed. This was made up of several subdepartments. Wing A was occupied by the Chemicals and Process Research, Rubber Chemicals, and Textile Chemicals Departments, as well as the more speculative Exploratory Research Department. Wing B housed administrative offices, the library, and the Literature and Patents Technical Group (also referred to as the patent liaison group).[13]

The Van Horne House, which after the war had served as the pharmaceuticals sales office, was turned over to the OCD general manager for installation of his offices and those of his assistants. The complete refurbishment cost around half a million dollars. Robert Long, when director of Commercial Development, worked upstairs and was in charge of the section that handled licensing arrangements with other firms. Long was responsible for successfully pushing important new glyoxal and phosphine processes with the Commercial Department. American Cyanamid became the only fully integrated producer of glyoxal, the simplest dialdehyde and a versatile chemical, employed extensively in textile-finishing products. Pilot-plant development, based on a method licensed to American Cyanamid by Laporte Chemicals of Luton, Bedfordshire, England, was undertaken at Bound Brook. Glyoxal was manufactured by catalytic oxidation of ethylene glycol at the Charlotte textile resin facility.[14]

American Cyanamid invested considerable efforts into phosphine manufacture, and R&D continued until the early 1970s. In this case the pilot-plant work and production took place at Welland, Ontario. Again the original invention was licensed, though it took many years to develop the ability to produce and market the product.

In 1958–59, American Cyanamid introduced Cyasorb UV24 ultraviolet absorber (2,2′-dihydroxy-4-methoxybenzophenone) to protect PVC plastics and surface coatings from deteriorating. It was one of a new range of products based on benzophenone derivatives, and developed during the mid-1950s at Bound Brook by William Hardy and colleagues, including Warren Forster and Ralph Arthur Coleman. "Cyanamid Chemistry gives longer life to many things under the sun!" announced advertisements for the absorbers, which were recommended for use in plastics, transparent wrappings, waxes, polishes, and safety glass. The OCD also developed Cyana purifying finish to inhibit growth of odor-forming bacteria, and the first resin for waterborne coatings. Cymel 300 resin, the first fully methylated melamine, was applied in the upgrading of coatings. The Textile Resins Department at Bound Brook supplied, under the Aerotex label, the various melamine and other synthetic resins for finishing purposes.[15]

In 1957 there had been further organizational and management changes that impacted considerably on the OCD. Responsibility for discovery of new processes was transferred from the technical organizations at various sites to the corporate Research Division, while the design of new plant and equipment was taken over by the Engineering and Construction Division (also referred to as the General Engineering Division), formed in 1956 following sale of the Chemical Construction Corporation. The duties of the Bound Brook plant manager, a post created in 1952 and occupied by F. B. Manker, now covered production, engineering, technical activities, plant services, purchasing, and personnel relations. Six Bound Brook manufacturing departments became formal business units: Intermediates, Dyes, Pigments, Acids, Pharmaceuticals, and Plastics and Resins. Dr. William Henry Bowman was appointed the OCD general manager (he was previously vice president at Jefferson Chemical Co., New York). In 1958 the OCD contributed considerably to American Cyanamid net sales of $525.1 million (compared with $1,829.2 million at DuPont).

Bowman was replaced by N. B. Conley in 1960. In the following year Conley handed over to Thomas P. Turchan. Also in 1961, American Cyanamid changed the general manager's title to president for each division in the company (though both designations were used), and the OCD headquarters moved from New York to Bound Brook. Most of the Plastics and Resins Division at Bound Brook was transferred to Wallingford. By then business had slowed down considerably, in the face of severe competition from home and abroad, particularly as a result of the revival of the German chemical industry. In January 1961, Garrett Hill, plant manager, in a New Year's message to staff had observed that "it is becoming increasingly evident that this is a year of challenge to all American manufacturers of chemicals." In response, extensive modernization began at Bound Brook. Richard R. Phelps, from March 1962 the new plant manager, reorganized the responsibilities of his staff. The Van Horne House, following restoration "to the splendor of the Colonial days when Gen. George Washington and his wife were dinner party guests of the Van Hornes," became one of the "most unique corporate division headquarters in the United States."[16] In 1961, the Refinery Chemicals Department had joined the OCD, which in this way gained three plants: Fort Worth (Texas), Michigan City, and Woodbridge (New Jersey). Cracking catalysts (Aerocat), antioxidants, corrosion inhibitors, and additives for lubricants were typical refinery chemicals, and included numerous organic sulfur and phosphorus products.

At Bound Brook, twenty acres of land along the Middle Brook were donated to the Borough of Bound Brook for recreational use. This was one aspect of an extensive good-neighbor policy that in 1959 had included the opening of the Boy Scouts' science-based Explorer Post 200—the first of its kind—at Bound Brook. In 1962, American

Cyanamid moved its corporate headquarters from New York to a new building at Wayne, New Jersey. In the following year the Explosives and Mining Chemicals Department was transferred from the OCD to the Industrial Chemicals Division.

Bound Brook employees were informed of company changes, promotions, modernization, and social and good-neighbor events through the in-house journal *Bound Brook Diamond* (formerly *Calco Diamond*). A special issue in 1957 marked the 50th anniversary of American Cyanamid, and another in 1965 the half-century of manufacture at Bound Brook. (From 1958, *Bound Brook Diamond* appeared twice monthly.) The *Bound Brook Diamond* also recorded the involvement of Calco employees in local affairs.[17]

Accounting Procedures

The divisional general managers, or presidents, were mainly engaged in planning, budgeting, and problem-solving activities framed within a specified time period. The General Staff, in contrast, was engaged in matters relating to strategic direction and long-range objectives. Financial planning was carefully integrated into operational and manufacturing decision making. Control of the business was meant to become more efficient through the availability to the General Staff of information based on extensive internal auditing, including budgetry constraints, costing procedures, profitability, and investment. Management accountancy functions determined the way in which divisions were organized.

In the fall of 1964, following three years of extensive modernization at Bound Brook initiated by Richard Phelps, he was appointed OCD manager of manufacturing. In the spring of 1965 he opined that "our past performance in the area of profit improvement has contributed much to the Company's growth, and it is recognized that an aggressive program of cost improvements is a necessity if we are to reach our long-range growth totals." However, despite reorganizations and modernization, there were ways in which the OCD was beginning to lose direction, particularly through new approaches to accounting procedures, generated at great expense but with very little meaning, as Von quickly realized.

About 1955 or perhaps a little later, our Accounting Department got a huge IBM main frame computer, capable of zillions of calculations. A totally different accounting system was installed. Each August the department manager and his staff were required (with the aid of the Sales Department) to prepare a budget showing how much of each product would be made during the coming year, the raw materials used, the yields and labor used. This data, together with the department overhead costs (including effluent) was given to the Accounting Department whose machine ground out books of cost sheets pricing every item. Even the overhead costs, which averaged 5–6 times the cost of labor, were broken down into various items and costed in an arbitrary way. (The only item that did not show up was the cost of the Accounting Department). During the producing year all of the data that could be gathered—amounts of raw materials used, their prices, yields produced, and labor used were entered into the computer and a comparison was made between the actual and the budget, and the variation was obtained. In most months this variation was negative.

What was wrong with this accounting system? First, it is difficult to predict what will happen 5 to 17 months later. This was especially true in the dyes business where fashion trends played an important part in determining volumes of individual dyes. Second, preparing this budget was a very complex undertaking with perhaps 500–1,000 products in the Dyes Department, and 150 in organic pigments. So naturally many errors crept in. They would be discovered during the year, but the Accounting Department refused to make changes, saying it was too difficult: "We will do it in the next budget." But in the next budget, everything would be so hectic [that] not much was done. And of course new errors were added. So after 25 years you can imagine the status of the budget. Third, there was some cheating. Certain products were favorites of the Sales Department but did not earn much money. The Sales Department (which had more clout than Production) would ask for help in making such products look good and the production manager would oblige by shifting some overhead costs over to be absorbed by more profitable products. After 25 years of such goings on, our accounting system no longer told us which products were profitable and which were not. In addition, the control of yield goals was lost. In making up budgets, managers could use any yield figures they wished. Since our variations from budget were usually negative, managers would tend to cut yield projections slightly each year in order to have a better chance to meet budget goals. In practice, yields did tend to decrease with the years due to deteriorating conditions, and nobody raised any alarms. We chemists tried to but were ignored.

One difficulty was that these unsatisfactory accounting procedures became the basis of calculations carried out by profit centers that later played important roles in the allocation of funds for new projects. Von observes that while "Victor King was right about the importance of cost accounting, our failings in this area, as I have described, certainly hastened our demise." The situation was not helped by the growing numbers of technologically naive senior managers, to whom scientific management meant nothing more than labor efficiency and cost cutting, nor by the transfer of divisional managers to a remote head office. This hierarchy structure prevented managers, including those with appropriate technical backgrounds, from building effective relationships with their immediate subordinates. There was also an overreliance on brand names, such as the melamine-product Formica. The Formica Company had been purchased by American Cyanamid in 1956, and renamed Formica Corporation.[18]

When asked how the new systems and less-efficient practices affected the corporation's sales and competitive position, Von's reply was that despite almost unrivaled technical excellence, "[w]e could not pass on to customers the costs of our inefficiencies." The problem was in part that fixed prices, linked to product standards—in contravention of antitrust laws—were strictly adhered to by dye manufacturers.

In all the years I worked at Cyanamid, the major dye manufacturers (DuPont, Cyanamid, National Aniline, General Aniline [GAF], and the Swiss companies) for sure charged the same for products of similar shade and strength. I think the lesser companies probably did the same. Therefore standardization procedures (by blending) were very strict. When we inadvertently shipped out a blend on the strong side to a customer who would then show it to a competitor, the latter would soon be on the phone complaining to our sales department. We would apologize and promise to be more careful. This ran afoul of U.S. antitrust laws and from time to time the industry was fined.

Everybody in the industry had the same standards for strength and brightness. These standards were not equal to the very best quality that could be made because it could not be done consistently or required more work and thus was more expensive. So, everybody blended, strong and weak, bright or extra bright and dull. So, you can see how quality as well as yield affected our profits. The same situation held true for organic pigments, although not quite as tightly.

Had the internal accounting rules and procedures within American Cyanamid been strengthened and more tightly controlled, the divisional managers might have been able to take measures that could have benefited the OCD, even despite the growing pressures on profits.

Technical Information at Bound Brook

With the formation of the new divisions in 1954, library and information services came under the aegis of the Technical Information Section (also referred to as Services). This included the Literature and Patents Technical Group, managed by a member of the Research Services Department who was responsible to the director of laboratories. The arrangement was identical with that introduced simultaneously at the Stamford laboratories.[19]

Technical Files controlled the distribution, indexing, and storage of notebooks, and was the main repository of all investigation orders (I.O.s) and reports (I.R.s). For many years Mildred Mangelsdorff (married name Day, then Elsner), sister of the medical officer, Arthur Frederick Mangelsdorff, had maintained this section, located in building 40.

Typical of the I.O.s stored in Technical Files was that issued on March 7, 1955, requesting an investigation into DuPont's crystalline 2,4-diaminotoluene, also known as *meta*-toluylenediamine (MTD, used to make Bismarck brown, etc.), which was more soluble than Bound Brook-made crystals and more stable than Bound Brook powder. The investigation was authorized by, in turn, the OCD, the Dyes Department Management Committee, the Department E Technical Committee, and the technical director, W. A Raimond. It included additional approval from the Medical Department's Dr. Mangelsdorff, estimates of work to be done, precautions, costs, and detailed instructions drawn up by N. W. Fiess.

The new research building, no. 4, provided much-needed space for improving the facilities of the main library, the repository of journals, books, and non-loan copies of reports. On July 1, 1957, the Bound Brook library was moved to Wing B. Referred to as the Research Division Library (though it served Bound Brook), it was the newest, though not the largest, of the Cyanamid libraries and, as was also the case with the information services, was run by female staff, including linguists and qualified chemists, some with research backgrounds.[20] The library had five sections: abstracts, current periodicals, company reports (including Bound Brook and Stamford), stack area, and a work area.[21] Long-standing head librarian Betty Cole's efforts to maintain the highest archival and library standards at Bound Brook over several decades were recognized by her election to the Special Libraries Hall of Fame. She and D. J. Wayne of Stamford (later W. T. Maeck) were associate editors of Cyanamid's *Research Division News*, edited by J. Allan MacWatt of Pearl River.

Cole's successor, in April 1963, was Joan L. Gallagher, a chemist who had previously worked in the Bound Brook laboratories. Gallagher supervised all library operations, and reported to Dr. Paul F. Dreisbach, group leader of the Literature and Patents Technical Group. Gallagher was to remain at Bound Brook until the end of 1982, as manager of Technical Information Services.[22] From around 1970, Gallagher was assisted by Marie L. Cline, who had assisted Mario Scalera's vat dye research group at Bound Brook until October 1949, when she joined the library staff, and developed skills in information science. Cline advanced from reference librarian to assistant librarian, prior to her resignation in 1955. Her place was taken by Robert G. Krupp. Cline returned to Bound Brook in 1958, this time joining the Literature and Patents Technical Group. At that time the only other person working with her in literature research for organic and pharmaceutical compounds was chemist Minnie Margaret Esslinger (B.S., Dickinson College, 1923; M.S., Ohio State, 1925), who had worked as a research chemist at Eli Lilly & Co. during 1944–48, prior to joining Calco. Later they were joined by Michael Kondas. Cline remained with the library until October 1982, two months before it was closed. Apart from their other duties, the librarians compiled extensive literature reports for the research chemists, and co-edited the successors to *Research Division News*, titled *Cyanamid Research News* from January 1959, and later *Research Quarterly*, circulated at Stamford, Pearl River, and Bound

Brook (and from 1961 at the Princeton laboratories of the Agricultural Division).

In the 1960s, Erwin Klingsberg emphasized the need for each research chemist to fully comprehend the literature matrix, "[b]ecause the chemist, within his own field, must know the library better than [the librarian] does, so that he is not dependent on her help. The chemist must have the sources in his field at his fingertips, including, for example, the indexing and organizational characteristics of the major sources like *Chemical Abstracts*, Beilstein, or encyclopedias, such as the Elsevier Encyclopedia."[23] This of course was totally dependent on the level of organization of technical information, which at Bound Brook was invariably outstanding, and a legacy of Betty Cole's dedication.

Era of Sophistication

The first edition of the dyers' and colorists' bible, the *Colour Index*, was published in 1924 by the British Society of Dyers and Colourists (SDC). The second, multivolume edition of this authoritative publication, the first volume of which appeared in 1956, was sponsored by both the SDC and the American Association of Textile Chemists and Colorists (AATCC). American Cyanamid's reputation in dye development and instrumental color measurement was reflected in the composition of the U.S. editorial committee, which included five Bound Brook scientists out of thirteen members. These five were W. W. Carr, who served during 1954–57; A. F. Clark, 1949; J. P. Matteis, 1953–55; A. L. Peiker, 1950–57; and E. I. Stearns, 1953–54. In addition, Stearns chaired or participated prominently in various AATCC committees.[24] Moreover, articles in *The Review of Scientific Instruments*, *Journal of Applied Physics*, and *Analytical Chemistry*, as well as numerous editorials, reviews, and chapters in books on the newer instrumental techniques of analytical chemistry, attested to the cutting-edge studies carried out at both Bound Brook and Stamford.[25]

Publications containing detailed technical information, and articles of more general interest for users of Bound Brook products, remained an important aspect of sales and service. Apart from the continuing publication of technical bulletins, the Dyes Department's technical services were made known through *Dyelines*, first published in 1955, and later known as *Dye-Chemlines*, with the catchy phrase "When it comes to Color, come to Cyanamid!" below the title.[26] The cover sheet was often reproduced as an advertisement in textile trade journals. Other promotional publications included, from the Rubber Chemicals Department, *Rubber Chem Lines*, launched in 1951, *Leather Lines*, *Paper Dyelines*, *Plastics Additives*, and *Plastics Dyelines* ("Dye specialists to the plastics industry since 1937"). In 1963 the latter promoted, for polystyrenes (production of which had grown almost 20 percent during the previous two years), Calco Oil Red ZMQ, a lightfast anthraquinone colorant for outdoor signs and automobile taillight fittings.[27]

Through Cyanamid's acquisition of Heller & Merz in 1930, Bound Brook made claim to be the "Headquarters for Paper Colors Since 1870." A little more accurately, American Cyanamid's advertisements in 1968 trumpeted "A Century of Service to the Paper Industry, 1868–1968." Among the leading sales and service personnel was Fred O. Sundstrom, who from the mid-1930s had played a key role in promoting Calco products for use in the coloring of paper. The colorants for the important processes of making paper white included Helmerco and Unitane (titanium dioxide) pigments, and Calcofluor fluorescent whitening compounds.[28] Textile products were extensively promoted to the dyeing trade through interesting shade cards and pattern books, eye-catching images, sales aids, and colored advertisements, incorporating novel designs by gifted illustrators and visual artists, and reproductions of specially commissioned paintings, including by Jerry Allison.[29] The Calco annual calendars, each based on a painting whose theme was some aspect of the history of dyes or organic chemistry, were much sought after for their outstanding artwork.

The end uses or methods of application of Calco colorants varied considerably, reflecting the growth in synthetic fibers, particularly polyester and acrylics, the demand for pigments used in carton and paper printing, and advances in chemical knowledge about the dyeing processes. These and other American Cyanamid products were also manufactured in overseas facilities.[30] The range of intermediates included *meta*-nitro *para*-toluidine, used in the manufacture of toluidine reds and Hansa yellow, a member of an azo dye class invented in 1909 at Hoechst. "Rapid" azoic dyes, in which color was formed on the fiber, were also popular. Cyanamid remained one of only eight manufacturers permitted to supply dyes as food colorants; in 1964, Calcozine Yellow FW met the stringent Food and Drug Administration's requirements for food-packaging paper. Other new dye products included liquid basic dyes to prevent color contamination in paper mills, liquid dyes for petroleum, pigments for ballpoint pen inks, liquid sulfur colors for cotton, and fiber-reactive dyes for cellulose, known as Calcobond, introduced in 1966.[31]

Isaiah Von emphasizes the role of Bound Brook's sophisticated technical service, and the availability of dyes endowed with a variety of properties, in marketing:

> The way we competed was through service, especially technical service, and through physical properties of our dyes (e.g. solubility, dispersibility, viscosity of paste types, etc.). We and DuPont had excellent technical service. We had one of the two most expert men in vat dye application, Ormand Clark; DuPont had the other. We used to publish books, bulletins and other aids. A number of our Technical Service men won the highest awards of the American Association of Textile Chemists and Colorists. We had a physicist on staff, Edwin Stearns, who pioneered color measurement instrumentally.
>
> Ormand and I visited many southern textile mills. He was so well known and respected that we would frequently enter a mill at the employees' gate instead of first registering in the office. One of the last things he did was to write a comprehensive volume on vat dye application. The manuscript appeared in typewritten form but was never printed as a book, due to the company's desire to save money. Ed Stearns was not only a very bright fellow but was also a pleasure to be with. I visited customers with him on several occasions, on account of both vat dyes and organic pigments. All this was vastly diminished in the 1960s. We were left with a skeleton staff and of course no publications.

Jay Leavitt opines that Stearns was "the authority on fluorescent brightening agents," and handled the field technical service for them, prior to moving into sales. Stearns was "very personable, excellent sense of humor, very, very smart."[32]

New Processes for Old Intermediates

Bound Brook's aromatic intermediates were the same as, or similar to, those manufactured during the 1915–30 period. It was here that the site excelled, and had the confidence to embark on massive programs for developing improved processes, including semicontinuous and continuous technology borrowed from the petroleum industry. Some, such as the diphenylamine and catalytic aniline processes, were highly successful; some, such as an anthraquinone process, were total failures, while problems with others, as described in the next chapter, contributed to the downfall of the facility around 1980.

Process improvements in the manufacture of aniline were driven by tremendous demand, particularly for the processing of rubber, and for use in the manufacture of dyestuffs, sulfa drugs, and detonators and stabilizers for explosives. Continuous processes were investigated by American Cyanamid, National Aniline, and other firms, probably encouraged by the developments in manufacture of intermediates as observed by Allied investigators at I.G. Farben factories. By the mid-1950s, National Aniline had introduced a continuous process for reduction of nitrobenzene to aniline at Moundsville, West Virginia.

Technically more advanced, however, was American Cyanamid's catalytic aniline, or Catan, process for continuous fluid-bed, vapor-phase reduction of nitrobenzene, as developed mainly at Bound Brook. Introduced at Willow Island in 1958, it replaced the messy iron-borings process that dated back to the late 1850s.[33] One of the engineers involved was Vanderwaart, a supervising chemical engineer in the OCD Process Engineering Department. "The plant design was given to Chemical Construction, the engineering arm of Cyanamid. I was assigned as a consultant and I was able to get most of my ideas incorporated into the plant."

The catalytic reduction had first been used on a laboratory scale in 1903 by Paul Sabatier, who employed a metallic copper catalyst. FIAT Final Reports 649 and 1313 described studies carried out at I.G. Farben with a copper carbonate catalyst. The fluidized-bed concept originated in Germany, particularly through the work of Fritz Winkler at BASF. During 1938–40 it was adopted by Warren Kendall Lewis and Edwin Richard Gilliland at MIT while attempting to overcome the problem of catalyst poisoning in Eugene Houdry's cracking process, then newly introduced into the petroleum industry. They merged the "moving-bed" concept with a "fluid," or finely divided, catalyst, as used from 1942 in large-scale fluidized-bed catalytic cracking of crude oil. (The moving bed enabled continuous regeneration of catalyst.)

The vapor-phase catalytic reduction was quite a challenge, as Vanderwaart remembered. Various copper-containing compounds were investigated, including cuprammonium nitrate.[34] Vanderwaart observed that the special feature of "[o]ur concept was to use a fluidized bed. Explanation—if gas is blown up through a bed of powder (of the right particle size) at the right velocity, the bed of particles visually resembles a boiling liquid. Hence the name."

The American Cyanamid Catan process was one of the earliest examples of penetration of fluidized-bed technology into the synthesis of organic chemicals, apart from production of petrochemical intermediates. The development work on the process and the catalyst, much of it empirical, was undertaken at Bound Brook, with contributions from Willow Island, Stamford, and Fort Worth.[35] The plant was engineered by Chemico. While fluidization offered the advantages of high heat transfer within the bed and uniform temperature, and ready application to continuous processing, there were known problems of low yields due to bubbling and mixing. Moreover, there was a dearth of published information available on fluidization in general, though this was to some extent offset by American Cyanamid's expertise in chemical engineering and plant design.

Instead of iron and acid, as used in the traditional process for generating hydrogen as reducing agent, hydrogen, made from natural gas, was added in excess.

A pilot plant had been built east of Bldg. 39. The reactor was a length of pipe (8-inch?) with a water jacket near the bottom. Hydrogen with nitrobenzene was admitted to the reactor below a grid and then up through the catalyst and exited through stainless micrometallic filters. We were set up for 24-hour operation. It would not be long before the product had no MNB [mononitrobenzene]—a day or two. Then a clean out and another try. In Bldg. 51 we had a bank of 1-inch glass reactors which were used to test new catalyst formulations. Soon we had the idea of impregnating silica gel with copper ammonium hydroxide and then reducing the copper to metallic copper; with refinement this became the catalyst of choice.

However, the life of the catalyst was short, and other Cyanamid chemists and engineers were consulted.

The suggestion came from the inventor of the sulfuric acid catalyst at Bridgeville [Selden] that sulfur [in the starting benzene] was the root cause. At great trouble the MNB shop prepared a batch of MNB from thiophene-free benzene. We withheld from using this precious material for some time. Then, in desperation, we committed our precious horde. Lo and behold our problems were solved.[36]

The design engineers were then instructed to scale-up the plant to full size and ensure that it was capable of producing over 1,000 lbs. of aniline per hour. Fortunately they were not restricted to laborious slide-rule tasks when performing the necessary calculations:

Most of it was straightforward state-of-the-art engineering. But control of the temperature in the reactor was a complete unknown. We got an analog computer, which was a set of components cabled up to solve simultaneous differential equations—Each section of the converter required a different equation. The key here was to assume an "effective thermal conductivity" and to match the end conditions for the several sections. This took Cam Hammersley and myself several months to accomplish.

The Catan plant at Willow Island certainly represented a leap into a new era. "The contrast between this plant and the old acid-iron reduction process is breathtaking. There was [in the old process] a line of reduction kettles with raising and lowering agitators. The rate of reaction was controlled by how deeply the agitators dug into the bed of iron filings. The completion of the reaction was observed by looking at the color of the refluxing liquid. All of New Jersey was scoured for sources of iron filings. Small machine shops were hunted down. The handling of iron filings by conveyor and hand trucks was a sight to behold. It is a wonder that men took the job." Vanderwaart pointed out that only one man was required to run the new aniline plant, though "there were several in the crew to monitor the instruments and to traverse the plant area to spot difficulties."[37] A further advantage of the Catan process was the ease of separation of the product aniline.

In 1964, the same continuous Catan process was introduced at Bound Brook. It replaced the iron-borings process in the manufacture of aniline, and completely overcame the problem of generation and disposal of vast amounts of iron-oxide waste, some of which was shipped off by rail to distant places such as Mexico. From 1962, ICI at Wilton, England, also developed a novel continuous vapor-phase hydrogenation process for aniline. The plant was commissioned in 1964.

In 1956, Vanderwaart was transferred from the OCD to what was about to become the new Engineering and Construction Division (ECD). The ECD was established after the sale that year of the Chemical Construction Corporation, located in New York "at 43rd Street, west of 10th Avenue. By far, not the best part of town. In a year, when the sale was completed, Cyanamid located its engineering activity in the Engineering and Construction Division." The ECD now formed the core of the corporation's engineering function, which, according to Jerry Forlenza, "was primarily to have responsibility with the estimating and the execution of the design and installation of major capital projects on a world basis. Major projects [were] generally defined as those involving $500,000 or more. In order to best carry out its mission the Engineering and Construction Division also followed, but did not undertake, research by the operating divisions in order to advise and to make sure that adequate data was accumulated to permit a satisfactory design for the proposed facilities."[38] Within a short time of his joining the ECD, Vanderwaart and colleagues were

> moved up to the Look Building on Madison Avenue between 51st and 52nd Streets. Now we were in luxurious surroundings. Jim Bourland was head of Process Engineering ... He soon moved into other things and eventually became a vice president of American Cyanamid. He was replaced by William A. Raymond. He was the best supervisor I ever had. But he was a tough boss. He would ask me what I was doing about something when I was just beginning to sense that there was a problem. More than anybody else he tried to make me do my job better. By no means was his opinion shared by others. He was disliked by many. We moved from the Look Building to the Time-Life Building,

Rockefeller Center. This was the center of the world. This was the center of power and it became intoxicating to some. General [Anthony Clement] McAuliffe was Division [General] Manager. He had had some activity in Chemical Warfare and was noted for the defense in the Battle of the Bulge. If you could not digest your thoughts to one page, he did not want to hear them. There was a problem at the Fortier plant near New Orleans. Bill Raymond said that no one knew less about this problem than McAuliffe, but that there was no one in Cyanamid whose judgment he would trust more. For when he made his decision he would KNOW!![39]

McAuliffe, a graduate of West Point, had parachuted into Normandy on D-day, June 6, 1944. He gained his reputation as a man of few words and quick judgment when in December of that year, as acting commander of the 101st Airborne Division at the siege of Bastogne, Belgium, he responded to a German demand to surrender with one word: "Nuts." After the war he held a number of senior military posts, including head of the Army Chemical Corps. In 1955, he became General McAuliffe, and was appointed commander in chief of the U.S. Army in Europe. He retired from the army in 1956, whereupon he joined American Cyanamid in New York, remaining there until 1963.

In February 1957, McAuliffe's division sent Vanderwaart back to the OCD Process Engineering Department as manager of a design section, to assist with new intermediates processes, probably including the final stages of the Catan process.[40] In sharp contrast to the success of the Catan process, however, the plan to manufacture anthraquinone [AQ] from naphthoquinone, condensed with butadiene (the latter now readily available as a petrochemical feedstock), turned out to be an expensive disaster. This project was perhaps stimulated by the high cost of Selden's phthalic anhydride relative to that of other manufacturers, and the need to seek out an alternative. Also, manufacture of naphthoquinone offered "a potentially inexpensive starting point for the synthesis and development of new products."

Around 1959, Vanderwaart was entrusted with bringing on stream the new process at Bound Brook. The first step in the novel anthraquinone process, conversion of naphthalene to naphthoquinone, as developed by the Research Division, was fraught with tremendous difficulties.

The development work had been done at Bound Brook, the process engineering by ECD and I forget who was the contractor. I was nominated to be ... the man in charge of the start-up. My first view of the plant was when it was about 98% complete ... We spent about $100,000 a month for two years and never made a pound of AQ. I cannot enumerate the mistakes that were made in the concept, design and construction ...

To recite some of the troubles. The first step was the vapor phase oxidation of naphthalene in a tubular fixed bed catalytic reactor. The naphthalene lines were steam traced to maintain naphthalene in a liquid state. But when the liquid naphthalene reached the converter, there were fires and explosions. On subsequent starts a siren would sound an alarm to clear the site. What a way to build confidence! So the naphthalene lines were electrically traced to maintain vapor state. One problem solved. The converter product was absorbed in monochloro benzene—MCB. Because of the volume of air, the absorber has a large diameter. A high circulation rate of MCB was required to match the air flow. Maybe 1/10th of 1% of the spray nozzle mist was carried out the top of the absorber by the air stream. This was a substantial fraction of the net production rate.[!] Solution—a variety of not very effective mist eliminators. The absorber product was counter-current extracted with water to remove phthalic acid. The combination produced intractable emulsions at the interface. No real solution. The phthalic acid was isolated in a centrifuge and then introduced to a dehydrator to be converted into phthalic anhydride. Nobody told the steam vapors to stay away from the phthalic feed point. The result was that it caked up tighter than the proverbial boiled owl's ass hole. The drive shaft coupling on the phthalic feed screw had a flexible coupling with four 3/4-inch stainless steel bolts. Trying to run this feed screw bent the bolts all out of whack. I kept one as a souvenir and passed it out at my going-away party [in 1977]. The phthalic anhydride was a by-product to be shipped to Bridgeville where there was a phthalic anhydride manufacturing plant and it accounted for more than 50% of the weight output. This does not make for good economics. The condensation with butadiene seemed to go well, but the final oxidation to AQ was a total loss. AQ had been made in the pilot plant, but not a pound in the plant. The research people finally became doubtful that the reaction was even theoretically possible.

In 1961, Thomas Turchan, the newly appointed OCD general manager, put a quick stop to the naphthoquinone-to-anthraquinone project. As Vanderwaart recalls, I was walking from the cafeteria in Bldg. 10 with the new General Manager, Tom Turchan, and he asked, "Van, do you know how much money you are spending?" I said "Yes, about $100,000 a month." He said "Do you realize that that is about $1,000,000 a year?" I said "Yes." He asked, "Do you realize that this is the profit on over $10,000,000 of sales?" I said "Yes." He said "Have you ever tried to sell $1,000,000 of anything?" It was then that I knew that the project was going to be abandoned. I was relieved of responsibility and Charles Pulsfort was brought in to close down the project. Eventually the plant was stripped to the ground ...

It was a very stress-filled activity. Al Potter and Bill Remillong were put on tranquilizers. Al Parker required psychiatric help. Glenn Watson once had 3 cigarettes going–one in his mouth, one in his hand, one in the ashtray and he was reaching for another. I came through it unscathed physically but not professionally. I think Ray Nee deliberately tried to rid ECD of those who had any connection with AQ and I had been center, front stage.[41]

Isaiah Von's reminiscences draw attention to other difficulties, particularly lack of sufficient evaluation of variables at the process research stage. This is when bench-scale laboratory investigations into economic viability are conducted, prior to the process development.

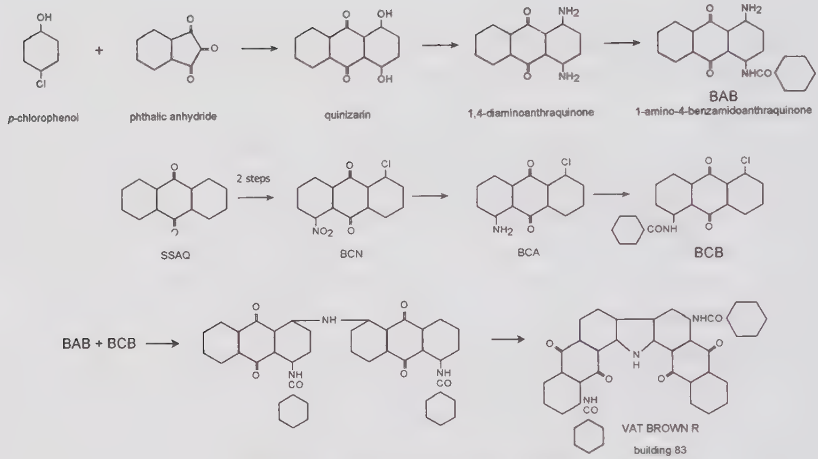
As I recall it was a three-step process in which naphthalene was converted to naphthoquinone (NQ), the latter condensed with butadiene and subjected to a third finishing step, the final oxidation. It turned out that the oxidation of naphthalene yielded about 1 part of NQ and 9 parts phthalic acid. This did not deter anybody. It was assumed the phthalic acid was to be sold as is, or converted to the anhydride and credited against the cost of the anthraquinone [AQ]. This was a flawed argument because it depended on sale of [this] by-product phthalic acid (or anhydride) to lower the cost. Unfortunately, however, phthalic anhydride was subject to a bitter price war, with its selling price as low as 9 cents. In addition to this flawed cost estimate, a worse sin was committed. Though a complete pilot plant was built, each of the three steps was piloted separately, i.e., each step was piloted from purchased or purified material. It was decided that the whole thing would be put together when the plant was built. I kept away from this project; the only responsibility we had was to assess the product if it could be used in manufacture of vat dyes. Over a 2-year period we received about 13 samples to test. All were dark miserable looking products and none came close to satisfactory.

The failure of the naphthoquinone project—most particularly a design based on what turned out to be incorrect assumptions about the condition and amount of material produced in two of the three critical steps—reflected the greater role that chemical engineers, as compared with chemists, generally played in major areas of process R&D within the U.S. chemical industry. It also, perhaps, indicated much-diminished levels of training in chemistry by chemical engineers, a situation that had given rise to quite separate cultural and institutional habits among many senior engineeers.

Certainly this was true at mid-century, and at American Cyanamid the tradition appears to have had a significant impact right into the 1960s. Had there been more involvement by chemists in the earliest stages of research, the various pitfalls that became apparent in this and other processes only after vast sums had been spent on setting up pilot and full-size plant might have been identified in time to bring about either cancellation or changes in design criteria. This, no doubt, is what Vanderwaart meant when he opined: "A project like this needs an outside observer. Those directly responsible have to believe in success. They cannot admit failure is possible. An outside overlook is necessary." Both management commitment and adequate chemical R&D were missing. Similar mistakes were to be made in the 1970s, with far greater impacts on the viability of the Bound Brook facility. By contrast, chemical engineers charged with making improvements to processes without changing the chemistry invariably succeeded.

It is perhaps ironic that not long before the naphthoquinone-to-anthraquinone (NQ–AQ) project was cancelled, Von's group embarked on a route that for certain vat-dye processes bypassed the need to isolate anthraquinone and purify it by sublimation.

> We had learned that DuPont used *o*-benzoyl benzoic acid [OBB] in place of AQ when the following AQ reaction took place in sulfuric acid or oleum [under which conditions the OBB condensed to afford directly AQ]. We decided to do the same with our processes and started a program about the time the NQ–AQ plant was being built. Within a year or so we were finished and we stopped making our sublimed AQ and only made OBB and its derivatives. Our Intermediates Dept. who sold AQ to various smaller customers insisted that we switch from AQ to OBB and we sold them OBB.



Vat Brown R (Bound Brook abbreviations)

This was a success, and contributed to the thirty-five different vat dyes made at Bound Brook with a total volume of around 700,000 lbs. of 100 percent dye type. Three of these dyes, Vat Jade Green, Vat Olive Green, and Vat Gray 2G-2, accounted for more than half of the total production, while sixteen, including the profitable Vat Brown R and Vat Olive T, accounted for 95 percent of the total.

By 1960, the production of many aromatics from petroleum, either from virgin naphtha or catalytically reformed naphthas, exceeded production from coal. This included 78 percent of toluene, 35 percent of benzene, and 90 percent of xylenes. As a result, coal-tar distillation at Bound Brook was closed down in 1962, and naphthalene refining ceased in 1965. In the mid-1960s, the possibility of moving heavy organic-chemical manufacture away from Bound Brook, as proposed by Alexanderson, was considered by the Commercial Development Department, probably with the intention of increasing the manufacture of fine chemicals such as pharmaceuticals and other high value-added products at the site. Also, labor was in short supply, even though residential areas were developing both south and north of the Raritan River. New and old neighbors were less than happy with the factory's releases of strong acrylate and skunk-like benzothiazole odors, quite apart from the poor condition of the Raritan River, created by the wastewater effluent releases. However, the decision was made to retain all existing operations at Bound Brook.

Incentives for Scientists

Strenuous new efforts were made to keep leading researchers at the bench without losing the status that normally came only with advancement to management level. The research fellow and research associate posts originally introduced by Calco in the 1940s were extended to all divisions in 1956. "The men so named can advance materially and still remain in experimental scientific work rather than depend upon the line organization for progression. Here they enjoy the prerogatives and distinction of departmental managers, but continue to serve where they are of the most benefit to themselves and the Company: in the 'idea areas.'" There were two research associates at Bound Brook at the end of the 1950s, one of them Erwin Klingsberg.[42]

Bound Brook and other American Cyanamid research scientists and technical experts regularly exchanged information at semiannual Skytop technical conferences, named after the location where they took place in eastern Pennsylvania, and also presented papers at the various Gordon Research Conferences held in New Hampshire.[43] After the new Bound Brook research building no. 4 on the Hill Property was opened in 1957, hopes were high that it would create opportunities for introducing many novel innovations. Improved research facilities and substantially better working conditions were among the incentives that encouraged self-improvement programs.

In keeping with the new emphasis on the role of corporate structure in guiding research, American Cyanamid's Dr. Alfred L. Peiker, director of the Stamford laboratories, delivered an address on February 27, 1958, in New Orleans, before members of the Louisiana Chapter of the American Institute of Chemists and the Louisiana Section of the American Chemical Society, on "Performance Evaluation of Research Personnel." Peiker discussed the scientific and managerial roles of professionals and some guidelines for management in using traditional organizational structures for research organizations.

The March 1958 edition of Cyanamid's *Research Division News* reflected the optimistic mood. Its lead item announced "Advanced Education Opportunities Now Open to Research Division Personnel. Cyanamid Developing Policy to Provide Support for Qualified Applicants." Funds were made available for the Research Division to provide three awards "to Outstanding Senior Professional Personnel for full-time work in research at universities or other locations," and three grants to complete residence or other requirements for a degree. The intention was clear. The awards would help to "further the development of senior professional personnel and enable the Company to remain abreast of developments in scientific fields." There were also provisions for leaves of absence without pay for advanced education leading to a graduate degree.[44] Elsewhere in the same issue, readers were advised that American Cyanamid's expertise was reflected in the regular contributions by its scientists to reviews of current progress in *Industrial and Engineering Chemistry*, *Analytical Chemistry*, and *Annual Reviews of Biochemistry*.[45]

In 1958, Joseph Paden was appointed research director, OCD, and, later in the year, director of research and development at the division. From this time the product research and process-development work of the Research Division reverted back to the operating divisions and departments. This was in accord with a new strategy of decentralization, which was also introduced at DuPont and elsewhere.[46] In December 1958, American Cyanamid announced that company-wide decentralization of research would be accompanied by the creation of a new coordinating body, the Central Research Division, based at Stamford. Moreover, "[i]t is anticipated that for an indefinite period there will be resident at Stamford several research units receiving their scientific direction from operating divisions." This meant that a major function of the Central Research Division was to undertake research assignments for the OCD and other divisions. James Bourland moved from New York to Stamford to become general manager of the Central Research Division; during 1958–60 he was assisted by Scalera. Elsewhere decentralization was soon accompanied by the creation of other "central" coordinating divisions, such as the Central Engineering Division.

In keeping with the reframing of research functions, *Research Division News* was renamed *Cyanamid Research News*. Staff transfers between Bound Brook and Stamford took place occasionally and greatly facilitated exchange of knowledge. In 1961, American Cyanamid opened the Agricultural Division's research center at Princeton, which within a few years had departments, sections, and groups dealing with a range of topics that included pesticides, entomology, metabolism and analytical chemistry, animal and plant industry research, and chemical process development. The corporation's facilities included fifty-two plants in North America, including Canada (where a new law favored manufacture rather than import), and fourteen overseas operations.

A Consultant's Overview

From the early 1950s, increasing numbers of academic consultants played important roles as advisers to American Cyanamid and other chemical firms. They were encouraged to apply their areas of expertise to problem solving, speculative research, suggesting new directions of enquiry, and advancing analytical techniques, including gas chromatography, introduced commercially in 1955 and installed at Bound Brook soon after.

The impressions of American Cyanamid consultants were eagerly sought out, as were summaries of their work, which were given extensive coverage in the research newsletters. An account by consultant Professor N(athaniel) Howell Furman of Princeton University provided a reflection of achievements in instrumental methods and techniques. The editor of the March 1958 edition of *Research Division News* advised readers:

> Dr. N. H. Furman, Professor of Analytical Chemistry, is one of a group of distinguished scientific consultants for Cyanamid. He has been head of the Department of Chemistry at Princeton, has served as President of the American Chemical Society [1951] ... The connection [with American Cyanamid] began in 1953 at the Bound Brook Laboratories primarily for electrometric methods in chemical analysis. The visits were gradually extended to more general analytical matters. In 1955, the arrangement was modified to alternate visits between the Bound Brook and the Stamford Research Laboratories. In 1957, an introductory visit was made to the Pearl River Laboratories.

This was followed with the personal impression of Furman, who outlined the work of the consultants, and emphasized their value to the firm's analytical capabilities:

There is no rigorous definition of the duties of a consultant. Short-range connections for attack on a specific problem or the development of a specific instrument are often made. There are all shades of arrangements, ranging from the specific to more general areas, where the conferences and consultations deal with matters ranging from those most directly related to the consultant's specific abilities to more general areas in development and research ... On the basis of experience with various Government agencies and companies in diverse lines, the writer believes that the American Cyanamid Company does one of the top jobs in efficient use of consultants.

Upon thinking over the analytical control, development and research activities and the physical methods groups that the writer has become acquainted with at the Bound Brook, Stamford and Pearl River Laboratories, one is impressed by the diversity of equipment and techniques and the high caliber and skills of the various groups ... The three excellent microanalytical laboratories each have different types of problems in addition to their standard operations, and have done much development of methods and research on their particular problems. Polarographic techniques have long been practiced on an analytical control and development basis at Bound Brook, and scientists at Stamford and Pearl River have, of necessity, explored and developed techniques and theories concerning the adaptation of the method to new classes of compounds. The Stamford Laboratory was the home of infra red developments under Barnes and Williams. At Pearl River, infra red is perhaps the major physical technique, and at Bound Brook strong use has been made of the method and this use is increasing. From the Bound Brook Laboratories have come many inventions and scientific contributions on the use of absorption spectroscopy in the ultraviolet and visible regions.

The small but significant research and analytical groups at Bound Brook and Stamford have followed parallel and complementary courses in exploring the further development and utilization of electrochemical methods. Coulometry, controlled potential electrolysis, chronopotentiometry, ion exchange membrane electrodes, thermometric (enthalpy) titrations and nuclear and radioactive measurements have been studied and developed.[47]

There were also opportunities for American Cyanamid chemists to take on consultancy-type roles within the corporation. At the Skytop technical conference held on October 5–7, 1958, the role for research fellows and research associates acting in this capacity was reviewed. As originally envisaged when these post were created in the 1940s, the aim was to keep the best research scientists at the bench. "Basically, the Research Fellow should be permitted the widest latitude in choosing his areas of investigation and in carrying out his research. His program need not necessarily be tied up with any existing commercial area." The researcher was assigned one assistant, until promising results suggested that a certain project justified the efforts of a group, or was transferred to a product and process research team. "The Research Fellow's responsibilities for the problem should then be only consultative."[48]

In December 1958, shortly after American Cyanamid announced that research activities were to be decentralized, James Bourland, head of the Central Research Division, was appointed chair of the corporation's Research Coordinating Committee.[49] From this time, new-product research of more immediate interest became the responsibility of each corporate division, apart from activities that were not specific to any one division. Other research would revert to the Basic Research Department at Stamford, which "will continue to investigate projects of long range future interest to the operating divisions and the Company as a whole." The transfer of all short-range R&D, and "certain other projects of corporate interest ... sponsored by Central Research," into business units was a strategy adopted during this and other reorganizations at American Cyanamid in the hope that it would focus more strongly on the needs of customers. What this meant is that, apart from Stamford, basic and long-term research at other divisions declined.

The MIT Practice School at Bound Brook

The need to encourage bright university graduates to consider careers in industry, in particular with American Cyanamid, led to the opening in 1958 at Bound Brook of a station of the Massachusetts Institute of Technology School of Chemical Engineering Practice. David Klipstein, a faculty member at MIT, and son of Kenneth Klipstein, was appointed first director of the station, which assigned a number of month-long site-related studies to groups made up of three or four visiting students. Klipstein served as director of the station until 1960, when his place was taken by Professor Harris Bixler, director of the school.

The MIT school, which provided facilities that enabled fulfillment of the experimental requirements for a master's degree in chemical engineering, operated what was generally considered to be a successful station at Bound Brook.[50] Its opening came at an opportune time for MIT, which had operated the chemical engineering practice-school program since 1916, but from the 1950s had begun to question its viability. One difficulty was the fact that industrial concerns were themselves highly sophisticated, sometimes more so than academic departments. In part this arose from the high cost of instruments that could not be accommodated within university budgets. No less problematic was the change in focus of chemical engineering from the sort of basic unit operations—such as filtration, pumping, evaporation, and distillation—and unit processes—such as nitration, reduction, oxidation, and sulfonation, which Norris Shreve had promoted—to the perceived need to comprehend better what was happening physically during processes. The approach and philosophy that had served so well since earlier in the century were no longer applicable.[51]

The Bound Brook practice-school station operated during the period in which the change toward an engineering science based on physical and physico-chemical laws, in keeping with the needs of many process-related industries, was taking place. The facility, though operating quite mature technologies, offered tremendous diversity. Moreover, its chemical engineers provided good examples of career trajectories. Typically this began at a development, design, or research department, such as the OCD Process Engineering Department. At the OCD, where batch processes were prevalent, new entrants often joined in a troubleshooting capacity, such as adapting new-product manufacture to existing equipment. Chemical engineers and research chemists were provided with opportunities for advancement to plant manager, section manager, works manager, general manager, production manager, and marketing manager.

In 1968, at a seminar on chemical engineering education that celebrated a decade of achievements at Bound Brook, MIT's Professor

Edwin R. Gilliland presented American Cyanamid with a plaque in recognition of the cooperation.[52] Cyanamid's William Allen pointed out that since 1962, the application of results from the projects had resulted in annual savings of $160,000, an excellent return when compared with American Cyanamid's annual contributions of $30,000. By 1975, however, inflation had driven salaries and operating expenses for the stations to levels that could not be sustained. When school director Professor Donald Anthony applied to the OCD for additional support, he was advised that "horrendous increases in the cost of raw materials and energy" prevented the corporation from increasing funding to the practice school.[53] The outcome was closure of the Bound Brook station. Altogether, 557 students completed 518 projects in the seventeen years of its existence, during which time there were twelve directors. The closure took place as American Cyanamid was downsizing several research programs and selling and writing off investments unrelated to its core businesses, such as expensive real estate developments that the corporation had embarked on around 1970.

The shift in the philosophy of chemical engineering from around 1960 did have a downside, as Herbert C. Brown of Purdue University—pioneer in the use of borohydrides and boranes in organic chemistry, and one of American Cyanamid's high-powered group of consultants and advisers—later remarked: "It used to be that chemical engineers studied a considerable amount of chemistry and chemists studied a considerable amount of engineering and there was a fairly close relationship. That seems to have fallen by the wayside."[54] As discussed earlier, this parting of ways no doubt contributed to the failures of the naphthoquinone process and the continuous processes that would be introduced at Bound Brook in the 1970s. Moreover, from the 1960s, the chemistry of dyes and aromatic intermediates, once a prominent feature of organic chemistry textbooks, was relegated to a few pages at best, and often dropped altogether from undergraduate teaching courses.

Creslan and Polyurethanes

During the war years Stamford had investigated the industrial production of acrylonitrile for use in the government's synthetic rubber program. American Cyanamid's Warners facility was the sole supplier, and this stimulated other applications in the high polymer field after 1945. In 1959, the polyacrylonitrile fiber Creslan, named after its inventor, Stamford's Arthur Creswell, was made at Bound Brook, where the new Fibers Division was located in building no. 103. The acrylonitrile was now supplied by American Cyanamid's Petrochemicals Division. Creslan, a copolymer of acrylonitrile and other acrylic components, such as methacrylamide, was invented in 1954 and originally known as Fiber X-54. It competed against DuPont's Orlon (invented in 1948, and introduced in 1950) and Chemstrand's Acrilan (introduced in 1952). These artificial fibers were not necessarily cheaper than the natural products, but offered higher performance through their novel properties, such as high resistance to outdoor exposure, to microorganisms, and, in many cases, to chemical attack. They were used, for example, in carpets, blankets, knitwear, sweaters, draperies, upholstery, and outerwear fabrics.[55]

As with other polymers, the introduction of new synthetic fibers could be achieved only if suitable dyes and pigments were available for their coloration. For several years the search for dyes for acrylic fiber was an important research area at Bound Brook. In 1957, the first basic dyes for acrylics were made on a pilot-plant scale, and limited quantities were manufactured, including at Willow Island.[56] By the end of the decade Bound Brook had introduced a range of Calcozine dyes for its Creslan fiber.

In 1960, to accompany the introduction of Creslan fiber for use in blankets and carpets, American Cyanamid opened a Fibers Application Laboratory, also in building 103 at Bound Brook, at first to assist technical service staff in the uses of Creslan. The Fibers Division set up a marketing group

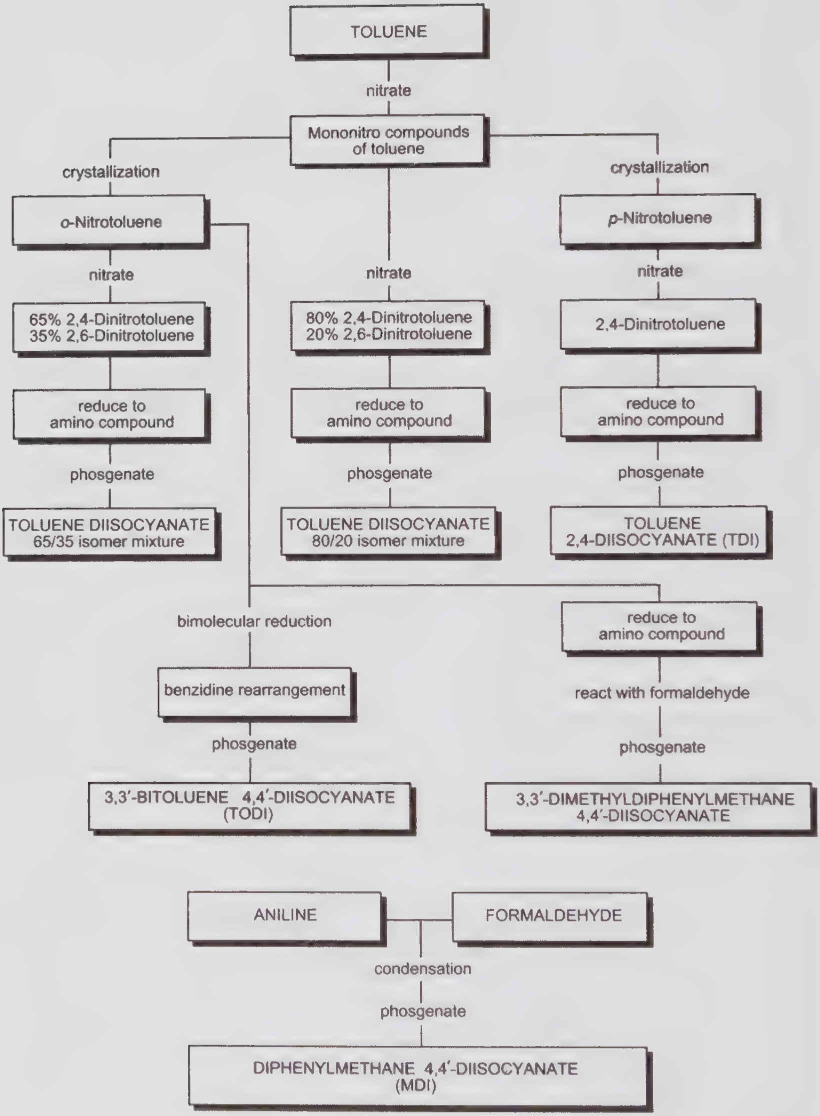
> based on a simple but incisive idea: "Show manufacturers how to sell their products rather than how to buy our fiber." From this came the concept of creative merchandising, wherein a mill or manufacturer was presented with a custom tailored program embodying some innovative merchandising idea specific to his operation ... Another concept included in the marketing operation was what came to be called Marketing by Objective. This involved developing

fibers specific to the end use to which they were put, either through modification or creation of new fibers.[57]

These initiatives pushed American Cyanamid's fiber sales to over 100 million lbs. in 1973. Creslan became an important addition to the range of polymeric products produced by American Cyanamid in the 1970s.

In April 1965, the Bound Brook facility began marketing Calcosperse dyes for polyester fibers such as Dacron. The annual use of polyester fiber had grown to 250 million lbs. in 1964, almost a fivefold increase over 1958. It was extensively employed in blends with cotton or wool for shirtings, dresses, suits, slacks, and outdoor wear. One of the most successful Calcosperse dyes was Calcosperse Red 2G, made by diazotization and coupling of 2-amino-6-nitrobenzothiazole to *N*-cyanoethyl-*N*-acetoxyethylaniline. There was, however, great emphasis on basic dyes, at the expense of these disperse dyes, due in part to prior difficulties with the latter. It was, as Jay Leavitt recalls, a mistake, an example of how at the departmental level "there were obviously some poor judgments of the direction in which to move, or not to move, e.g. the dyes department choice of going after new basic dyes for Orlon [acrylic fiber] despite a marketing consultant's (correct) conclusion that disperse dyes for Dacron [polyester] was the way to go. But early poor experience with disperse dyes for acetate had soured the departmental management on this group."[58] Also newly available was Calcosyn Blue RP for polypropylene fiber.

One group of polymeric materials developed extensively at Bound Brook was based on the availability of nitro derivatives of toluene, and of aniline. These were the polyurethanes, for which the highly reactive isocyanates, made from the nitro compounds through reduction and phosgenation, or from aniline through condensation with formaldehyde followed by phosgenation, were essential. The first use of the important intermediate toluene diisocyanate (TDI), made at the I.G. Farben Leverkusen works, was, at least by 1941, in preparation of rubberized fabric. Reaction with hydroxyl-containing compounds afforded urethanes, RO–C(=O)–N–, first polymerized by Otto Bayer at Leverkusen. He developed polyurethane foams during the war, and details of the processes were obtained by the Allied commissions.[59] Drawing on the Allied technical reports and



Manufacture of isocyanates from toluene and aniline for polyurethanes

Adapted with permission from "Urethane Plastics: Polymers of Tomorrow," *Industrial & Engineering Chemistry* 48 (September 1956): 1383–91, on 1388. Copyright 1956 American Chemical Society.

probably ICI technology, diisocyanates were made at Bound Brook from around 1950. Production of polyurethanes, by reacting diisocyanates with a dihydroxy alcohol such as ethylene glycol, began in the United States during 1954, and by the following year were available on a commercial scale as adhesives, coatings (using a polyester resin instead of ethylene glycol), foams, and elastomers.[60]

The main American manufacturers of the intermediate diisocyanates were DuPont, Mobay Chemical Company (a joint venture of Monsanto and Bayer, established in 1954, and later wholly owned by Bayer), and National Aniline. Though American Cyanamid was not a pioneer in this business, Bound Brook chemists did develop a novel route to diisocyanates. William B. Hardy, while section manager, Exploratory Research, during 1959 to 1964, oversaw new processes for intermediates, notably the synthesis of diisocyanates directly from the reaction between a nitro compound, a hydroxyl compound and carbon monoxide, at high pressure, high temperature, in the presence of a catalyst.[61] These intermediates, the development of which from a commercial perspective consumed perhaps too much time, according to Jay Leavitt, were converted into the polyurethanes. Hardy took over Research Services in 1964, and in 1966 was appointed manager of Intermediates Research and Development. Leavitt, Hardy's replacement as manager of Exploratory Research, rates him an "an outstanding research administrator."[62]

Spandex stretch fiber, based on polyurethanes, was first manufactured in the United States in 1962. DuPont's product was called Lycra. Two years later, a spandex fiber plant became operational at Bound Brook in building 85, then occupied by the Plastics and Resins Division, now reduced in size, and the Rubber Chemicals Department. The product was called Numa. In 1969, polymer specialist George W. Schael Jr. joined Bound Brook from Upjohn Co. (where he had supervised the physical testing laboratory) as group leader, Elastomers Physical Chemistry Group and Physical Testing Laboratory. Later he became involved in process development for polyurethanes and other elastomers. In 1973, Schael was appointed elastomer marketing specialist for the Rubber Chemicals Department, with special responsibility for Cyanaprene thermoplastic polyurethanes.[63] The same department also manufactured Cyanacryl acrylic rubber elastomer.

Reorganization, Computer Color Matching, and New Laboratories

Two notable individuals connected with Bound Brook in the 1960s would later oversee the facility as presidents of the OCD. They were Ben H. Loper and Jerry Forlenza. Loper managed the Dyes and Textile Chemicals Departments from 1961 until 1964, the year in which they were merged. He had joined American Cyanamid's Stamford laboratories as research engineer in 1950, with a B.S., majoring in chemical engineering, from Illinois Institute of Technology.[64] In 1955, Loper was appointed technical director, Catalyst Department, New York, and in 1958 became manager, Refinery Chemicals Research Department, Stamford. During 1964–65, Loper was president of the Textile Dye Institute, formerly known as the Vat Dye Institute. He was the OCD president in the mid-1970s.

Forlenza was appointed assistant to Tom Turchan, then OCD president, in 1962. He held bachelor's degrees, majoring in engineering and chemical engineering, from Columbia. For Forlenza, Bound Brook was an important training and learning experience, a prelude to later appointments as director of the Central Engineering Division, and presidency of, successively, the Plastics and Resins Division, the Industrial Chemicals Division, and the OCD, the latter post taking him back to the affairs of Bound Brook in 1977, as successor to Loper.

Turchan and Forlenza structured the OCD along functional lines, with support coming from a director of R&D, Joseph Paden; a manager of manufacturing, Richard Phelps; and director of marketing, Hugh Puckett.[65] Forlenza explains that the OCD incorporated

> a number of departments as profit centers with control over the marketing, manufacturing and research for their respective business areas.
>
> In addition to the departmental research I maintained a separate divisional research group reporting in line to me. This independent divisional research group would generally work on long-range type projects. The departmental research groups tended to work on shorter range projects which were more responsive and reflected more quickly in the departmental profits center.[66]

The other American Cyanamid divisions, however, were not necessarily structured in the same way, but according to "who was at the top and what he favored." Moreover, Bound Brook was effectively a collection of subunits. Each product department had three managers, who reported to the department manager, who in turn reported to the OCD president.[67]

We had reporting to us a minimal staff which included the directors of marketing, manufacturing and research. The line organization for the division consisted of a number of departments each of which had responsibility for a defined business area. In our case this included the dyes department, intermediate chemicals department, rubber chemicals department, etc. Each of these departments was headed by a department manager who had reporting to him a sales manager with line responsibility for the dedicated sales force for his business, a manager of manufacturing with line responsibility for the production of products, and the research manager with line responsibility for departmental research.

As for the management of research programs within departments, Forlenza recalls:

This structure did present some dichotomy but it made for a strong focus on the specific business area together with line responsibility for the business area. This structure was our innovation. Other companies such as DuPont tried to get the same emphasis by employing the dual line of control, establishing a line organization for sales for all the product lines, with a number of product managers each responsible for developing the plans and strategy for a specific business area. Each of these two lines separately reported to the division management. My preference is strongly for the former.[68]

Presidents of divisions were "extremely capable and honorable people," who met once a month at a "round table." They were also "very powerful, and could steer wherever they wanted." Each year, the presidents formulated five-year programs, outlining "where they were going, what they felt they might be doing," and dealing with capital matters.[69]

After George W. Hedden was appointed Bound Brook plant manager on July 15, 1964, all closely connected activities and responsibilities were further consolidated and placed under the control of separate managers.[70] Increased emphasis was placed on a profit-improvement program, the Commercial Development Department was expanded, and a long-range plan superseded the earlier five-year forecast method for achieving specific objectives. However, as Forlenza notes: "The department managers were so influenced by their profit and loss statements that long-range research would not get the attention it deserved and tended to be underfunded."[71]

The Bound Brook R&D departments included Dyes Research and Development, Exploratory Research, Rubber Chemicals Research and Development, Process Development, Research Services (Section I and Section II), Intermediates Research and Development, Textile Chemicals Research and Development, and Systems Analysis. Charles Maresh was manager of Research Services Section I, where in 1963 research associate Eugene M. Allen was in charge of the recently arrived Colorant Mixture Computer (COMIC), introduced in 1958 by color consultants Hugh R. Davidson and Henry Hemmendinger (both previously at GAF). Also in 1963, Bound Brook announced an overnight Computer Color Matching (CCM) service for selected customers. It was the first such service offered in the United States and was developed jointly by Allen and Edwin Stearns. This new computerized dyes-standardization program assured "speed and dependability in a production area which for 50 years has depended solely upon the abilities and upon the limitations of the human element." In 1965, *Chemical Processing Magazine* voted CCM the recipient of its Valaar Award, that recognized contributions toward more efficient and effective operation of plants in the chemical industry. In 1983, Allen received the Inter-Society Color Council's Godlove Award for his contributions toward color measurement. Jay Leavitt points out that these advances did not altogether exclude the human element: "Instrumental matching of shades reduced but I don't think ever replaced dependence on the eye. The Sales Department office had Nat Koenigsberg whose ability to discriminate between two slightly different shades was legendry."[72]

Early in 1965, a Sales Information Center was set up in the Sales Service Department for mechanical control of statistical and other data on customers and products. Dyes and textile chemicals still contributed considerably to the 700 chemicals manufactured at

Bound Brook, from which over 1,500 marketable products were produced. There were 134 buildings and 3,500 employees, including the research scientists assigned to the buildings on the Hill Property and newly modernized laboratories in the manufacturing area. Around this time, the research staff included 76 men and women with bachelor's degrees, 29 with master's, and 88 with Ph.D.s.

In the fall of 1965, Wing C of building 4 (also referred to as building 4-C) on the Hill Property and new offices and laboratories in building 39 were completed. Opened fully in December, the three-storied Wing C, with 64,000 square feet of floor space and room for 180 staff, had been planned according to "a new concept in laboratory design which has been adopted by several major research organizations in the past 10 years." It was occupied by Dyes Research and Development, Intermediates Research and Development, Analytical Research, Research Services, and the process-development group for pharmaceuticals.[73] Research in Wing C included physical chemistry, instrumentation, and color physics. Wing A of building 4 continued to deal with textile and rubber chemicals, including elastomers, and contributed to the development of polymeric materials. The latter involved a move into the science of materials with Cyanacryl acrylic elastomers specially developed for engine and transmission parts in the automobile industry. There was a strong emphasis on additives for plastics, generally manufactured in the Intermediates Department.

Systems Analysis (a location of R&D personnel created in 1954, and then known as Statistical Analysis), the main process-development unit, and R&D pilot plant remained in the manufacturing area, across the railroad tracks in buildings 10, 39, and 51, respectively. They engaged in analytical research, physical chemistry, and other functions, as did laboratories in buildings 3, 11, and 41. An IBM 1620 computer for technical computing had been installed in building 10 in 1961, and was replaced by an IBM 1800 in 1965. Also in 1965, the Accounting Department received an IBM 1460, replacing the 1401 model obtained in 1963. Ben Loper emphasizes that Bound Brook staff included a number of highly competent computer experts. Those that worked with Systems Analysis undertook various tasks to enhance the applications of instruments in Wing C. This included the tie-in of the IBM 1800 computer, located in the manufacturing area, with six gas chromatographs in Wing C, situated about a third of a mile away. Such relatively long-distance transmission of precise information was rare in 1968–69 (IBM believed that it was unique). Its success encouraged the additional tie-in of a further six gas chromatographs, the new nuclear magnetic resonance—or NMR—spectrometer, and two visual spectrometers.[74]

Chapter 7

A New Era

"The biggest acquisition [in 1929] was Calco which formed the foundation for our dyes business as well as a pharmaceutical business that would grow into the company's largest business in the '80s."—*Cyanamid at 85* (Wayne, N.J.: American Cyanamid, Public Affairs Division, 1992), 3, a special section of *Focus* 13, no. 3 (1992).

Despite extensive modernization in the manufacturing area and the opening of new laboratories on the Hill Property, the dominance of Bound Brook in the affairs of American Cyanamid waned considerably during the second half of the 1960s. In part this was the outcome of the concentration on what had been its past strength, aromatic organic chemistry. The mature commodity chemicals, some made much as they were a century earlier, while still much in continuous demand, no longer generated the levels of profit, nor potential for diversification and expansion, that products of other divisions, particularly pharmaceuticals, appeared to offer.

The Organic Chemicals Division (OCD) produced—now almost exclusively from petrochemical feedstocks—dyes, intermediates, refinery chemicals, rubber chemicals, and textile chemicals and resins, and represented about 15 percent of the corporation's property. It was exceeded in size by the Lederle Division. Bound Brook produced intermediates and finished products for the Lederle, Agricultural, and Fine Chemicals Divisions, organic pigments for the Pigments Division, and acids for the Industrial Chemicals Division. Older dyes still in production included *para*-rosaniline, of which 285,000 lbs. were made each year from aniline and formaldehyde in the "Organic Pigments Department."

The 575-acre Bound Brook site, with a staff of over three thousand, remained American Cyanamid's most diversified manufacturing facility, though it was much smaller than Willow Island. It was also less than half the size of DuPont's 1,450-acre Chambers Works at

Deepwater Point, which employed six thousand people. In 1967, Bound Brook was served by fifteen miles of railroad track, seventy-three tank cars, and two diesel locomotives. John Allegaert, then serving his last year as American Cyanamid president and first year as chairman, observed that "currently four vice presidents have had service at Bound Brook, as have five divisional managers, seven assistant general managers (or equivalent), and six plant managers." Of the more than three hundred American Cyanamid research scientists, around one-quarter worked at Bound Brook on aromatic, heterocyclic, and aliphatic chemistry, polymer and elastomer chemistry, sulfur and organo-metallic chemistry, and physical and physical organic chemistry. Few of them realized that the last edition of *Research Quarterly,* in December 1968, was to precede a period of cutbacks in research activity, which no longer appeared to be generating products that contributed to the balance sheet.

American Cyanamid Presidents: 1907–1990

1907–22 Frank S. Washburn
1922–50 William B. Bell
1950–52 Raymond G. Gaugler
1952–57 Kenneth C. Towe. In 1957 he was appointed chairman of the board, a new post. He retired in 1958
1957–61 Wilbur G. Malcolm, president and chief executive officer (CEO); chairman and CEO, 1961–66
1961–65 Kenneth H. Klipstein, president and chief operating officer (COO)
1965–67 John Allegaert, president and COO; chairman, 1967–68
1967–72 Clifford D. Siverd, president and CEO; chairman and CEO, 1972–75
1972–79 James G. Affleck; chairman and CEO, 1976–84
1979–90 George J. Sella Jr.; chairman and CEO from 1984

Notes: Affleck joined American Cyanamid as a research chemist. From 1954, Sella had worked with the Rubber Chemicals Department at Bound Brook. During 1958–61, Thomas Perkins was chairman of the board. In 1961, the bylaws were changed to make the chairman also the CEO. The president during 1991–93, was Albert J. Costello, who started his career with American Cyanamid in 1957 as a chemist in the Pigments Department at Bound Brook. In 1993, he was appointed chairman and CEO.

Cyanamid's research efforts in the physical sciences and, increasingly, biology-based businesses, were carried on with the combined facilities of the four research centers in the United States—Bound Brook, Pearl River, Princeton, and Stamford—and another in Geneva, Switzerland. The latter, the $1 million Cyanamid European Research Institute, inaugurated in 1959, was intended to bring about new scientific breakthroughs in chemical and biological sciences, not necessarily with immediate potential for commercialization, based on collaboration between European and American scientists. According to Erwin Klingsberg, it was a "magnificent site overlooking the Lake of Geneva." The institute's "brilliant but somewhat erratic" vice president during 1960–61, Mario Scalera, staffed it "with outstanding and highly productive scientists" from European countries.[1]

Group directors included Dr. Robert F. Hudson, Theoretical Organic Group, Dr. E. A. Lucken, Instrumental Analysis Group, Dr. Erwin Weiss, Synthetic Inorganic Chemistry Group, and Dr. Christian Klixball-Jørgensen, Theoretical Inorganic Chemistry Group. The Geneva researchers published profusely, and group directors made annual pilgrimages across the Atlantic Ocean to visit American Cyanamid research laboratories, but apparently all to little or no avail when it came to useful innovations. From a commercial perspective, opines Klingsberg, Geneva was a failure. It was closed down in 1969.[2] Jay Leavitt considers that the closure of the European institute was premature, since it was given insufficient time to develop.

New OCD Presidents and Managers

Allegaert's emphasis on the number of managers and technical experts associated with Bound Brook who eventually rose to high positions elsewhere at American Cyanamid suggests one reason why the overall management there eventually became less effective. In the words of Isaiah Von: "Too much talent was bled away … I don't know that the people at Bound Brook were smarter than personnel elsewhere, [but it] was the largest and most diverse location, people who worked there were exposed to a greater variety of experiences and so were a little more suitable to be moved around."

Newcomers with little background in Bound Brook technologies arrived with a head-office philosophy that hardly suited manufacture of aromatic chemicals. Since 1915, Bound Brook technical personnel and scientists had learned chemistry by its application, by imitation, and by innovation. In the course of gaining experience they developed a coherent background of site-useful knowledge, much of which was codified in the notebooks and various reports. Von opines: "I think that as Cyanamid became more and more centralized and as layers of administration were added over the years, less and less attention was paid to the background and experience of people who were moved around. Our OCD general manager during the '60s [Turchan] used to say that a good manager could manage anything, which of course is nonsense. Also, of course, there was a lot of politics and even nepotism." A fairly consistent picture emerges that in the opinion of Bound Brook scientists, the philosophy based on a manager being capable of managing anything was not necessarily true. Indeed, far from it. Thus Hardy has in mind certain departmental managers who were not qualified to direct research activities, with an inevitable decline in the management system and innovation.[3] Von, another seasoned veteran who had witnessed the many changes since 1950, recalls how engineering and computing miscalculations, communication failures, and management pressures plagued modernization of azo-dye technology:

As an example of the kind of management and atmosphere we had during the last 15 years at Bound Brook, I will relate the following episode with which I was intimately involved.

When I was transferred to the pigments manufacturing department in 1965 I had a boss whose previous experience was in industrial engineering. He was "hands off"–if you didn't bother him, he didn't bother you. He was made manager of our Willow Island plant in 1967 and his replacement was a young fellow, Mr. X, who was friendly but also very ambitious. X had a B.A. in mathematics and joined Bound Brook about 1960 in a group called the Systems Analysis Group, devoted to developing uses for the computer other than for accounting. He soon became head of this group and quickly developed a reputation for using the computer as an aid in various scientific and other uses [including in instrumental analysis]. In 1967, he was promoted to manager of the pigments manufacturing department and thus became my boss.

He confided that he was on a "fast track," being groomed for higher managerial positions, and would spend 3 years with us learning manufacturing operations. He said that during his time with us he would like to see something really spectacular accomplished. Being aware of corporate technology philosophy, he suggested making one or more major azo products continuously. I explained to him that since the properties of an organic pigment depended as much on the size and shape of the pigment particle as on its chemical composition, it would be very difficult to develop and control continuous reaction conditions relative to batch processes. This was especially true [of Bound Brook] since our biggest volume product amounted to only about a million lbs. per year. I suggested instead (without knowing very much about computer technology) that perhaps azo pigment batch making could be automated with the use of a computer. I thought this might work because the azo processes all involved simple steps in water such as solution, stirring, heating and cooling, pH correction, etc. The reactions involved were just diazotization, coupling, and precipitation of the pigment. However, in order to get consistent results that would require minimum or no blending, all steps have to be carried out in consistent fashion. This was difficult to do, given the operators and supervision that were available ... I thought that with automation we would not only save labor but would achieve consistency. My one proviso was that the automated processes would have to duplicate the existing manual processes in all details.

X thought this was a very good idea and discussed it with the current head of the Systems Analysis Group, whose project it would be. It was concluded that this project would be economically feasible, with an expenditure of several million dollars for an IBM1800 mainframe computer, programming costs and additional instrumentation and equipment [Some of this expense may have been spread by the use of the computer in other projects, such as the computerized linkup of analytical instruments used in research]. In the presence of both the presidents of Pigments and OCD, a laboratory presentation was made showing an appropriate diazo solution being run into a beta-naphthol solution to form a red precipitate controlled by a computer in another building. This won the support of both presidents and the project was on.

In 1968 and 1969, the project moved forward, with the programming of the processes, the design and installation of equipment. The computer was installed in a special air conditioned room built especially for the purpose. In early 1970, we were ready to go, and if I remember correctly, by then Mr. X was gone to a job in sales. I remember the first trial vividly. The first step went OK. The second step was to be a pH adjustment and this took a very long time. So I already had doubts. Further, I was suspicious because a month before, five of the Systems Analysis Group, including their leader, had resigned and all gone to work for the leader's uncle in Chicago.

To come to the point, the total project was a disaster. To make any product at all, considerable human effort was required and even then much of the quality was poor. My group was put to work to try to keep saleable production going and to try to improve things. It became apparent quite early what the problem was. The Systems Analysis Group had grossly underestimated the complexity of the project. Much more programming and computer memory (very costly at that time) were required. So without telling us, they started making short cuts and other changes. For example when more than one step at a time was supposed to take place, they put the steps in a queue, throwing the timing all off. From time to time when blending could not correct our problems, we had to discontinue the automation for a while in order to make saleable stuff. We had so much off-grade material that the central warehouse could not hold any more and we were forced to store drums on decks outside three layers high.

After about six months, I and others concluded that this project was beyond repair and should be abandoned. However, management, particularly the two presidents, John Ludden of Pigments [formerly with the Calco Division at Willow Island] and Tom Turchan of OCD, would not permit it. We struggled on.

In England, ICI was also investigating computerized control in the manufacture of azo colorants. The outcome, a new plant that began operating at the Huddersfield facility in 1972, was highly successful, mainly due to the fact that batch processing was retained. At Bound Brook, however, as Von recalls, the main contribution of the continuous azo process was as fictitious savings in production costs as displayed in annual reports.

Apart from the technical problems and incomplete calculations, there were serious constraints based on the systems of awarding bonuses, dating back to the post-war arrangement with labor over production, and of profit reporting, or at least of estimates on savings, that increasingly became a matter of providing figures that pleased the management.

One more thing. In the 1960s Cyanamid started a Profit Improvement Program (PIP) throughout the company. Anybody working on a project that would save money would describe the project and estimate what it would save. It could be in technical, production, sales, even administration. All the savings from the entire company would be compiled and published in the Annual Report. At first, our estimates were carefully made, with raw materials from the purchasing agents, labor estimates from Industrial Engineering, steam costs from the engineers, etc. Gradually it became noted that the estimates were never challenged; in fact, the bigger the numbers the happier the management seemed to be. So estimates became more casual and even somewhat inflated. For azo automation, we estimated $300,000/yr. This number was never withdrawn, since the azo project was never formally closed. I laughingly referred to our return to normal operation as "the manualization project." My Pigments Division technical liaison went a little further. He said, "Why don't we claim some more savings? How about $100,000?" So we did![4]

This was typical of the situation that the fifty-four-year-old Clifford D. Siverd inherited when he was appointed president and chief executive officer of American Cyanamid in 1967. However, then the overall mood was still one of optimism.

In 1968, Joseph A. Schmidlien was appointed president of the OCD. A new acquisition that year, following research at Bound Brook in the 1960s into Cyasorb infrared absorbers (benzophenone derivatives) incorporated into plastics, was the Glendale Optical Company, a firm that specialized in industrial safety products. It was later renamed Glendale Protective Technologies, Inc.[5] On September 12, Tom Turchan, then vice president and chairman of American Cyanamid's Global Coordinating Committee, announced increased production of Cyasorb products at Willow Island and the Cyanamid Dutch factory at Botlek, near Rotterdam. The same year saw the opening at Bound Brook of the Pigments Division's magnetic oxides R&D department. Production of pesticides, made by processes developed at Bound Brook, was also increased.[6] During 1969, manufacture began at Bound Brook of an important animal health product, Tramisol levamisole (an imidazothiazole), a broad spectrum dewormer for control of lung, stomach, and intestinal worms in animals. Another novel product, invented and developed at Bound Brook around 1970 by Exploratory Research manager Michael McKay Rauhut and colleagues, was chemical light—Cyalume—a "unique self-contained liquid lighting device," which, since it lasted around twelve hours, was used in sailors' rescue packs, in gimmicks for children, and in chemical demonstrations.[7]

In 1967, Edwin Stearns received the Olney Medal of the American Association of Textile Chemists and Colorists (AATCC), in recognition of his contributions to textile wet processing, and the Inter-Society Color Council Godlove Award, for undertaking the first calculation of a color match from numerical data. Two years later, in June 1969, the AATCC signed an agreement with the British Society of Dyers and Colourists (SDC), whereby the two organizations agreed to jointly publish the third edition of the *Colour Index*. In the city hall at Bradford, in the presence of the mayor, the AATCC presented its British counterpart with the newly published translation by Sidney M. Edelstein and Hector C. Borghetty of the first printed book on dyeing, the color index of its day, *The Plictho of Gioanventura Rosetti* (1548). In September 1971, Stearns, as president of the AATCC, inspected three volumes of the new *Colour Index* at Perkin House, Bradford, the offices of the SDC. A specially inscribed set was presented to the AATCC at its golden jubilee conference, held in Boston during October 1971.[8] On that occasion a special luncheon honored charter members of the AATCC, includings R. Norris Shreve, who had served on the editorial committee for the first edition of the *Colour Index* (1924). However, and notwithstanding the high profile of Bound Brook among dyers and colorists, and celebrations of advances in color control, the demand for Calco products in the textile industry had diminished considerably.[9]

The 1970s

During the decade ending in 1971, sales from traditional chemical products dropped from 42 to 32 percent of the corporation's total. In 1971, some 27 percent of sales came from building and consumer products, 21 percent from medical products, and 20 percent from the Agricultural Division. Bound Brook remained an important supplier of key intermediates and ingredients to Lederle—increasingly the major contributor to American Cyanamid's annual profits—and the

Agricultural Division. Two new acquisitions reflected growing interest in consumer products, Shulton (toiletries and perfume) and the Breck Company (shampoo), while a start was made on the purchase of Formica's international operations (completed in 1977, from De La Rue in England).

Nature also contributed to Bound Brook's struggles. August 28, 1971, saw the most severe flooding ever of the facility. It was also "the greatest ever along streams of the Upper Raritan and Raritan Valley. [The water] crested on the Raritan at Bound Brook at a reported peak of 37.47 feet—four feet higher than the previous peak in 1903. Homes, business places and industries were flooded with the neighboring Borough of Bound Brook particularly hard hit. New Jersey was declared a disaster area and Cyanamid Bound Brook was seen as 'the most devastated plant in the State' by the state commissioner of labor and industry."

This flood, the result of Hurricane Doria, had originated not in the Raritan but in the Middle Brook, which met the Raritan just east of the factory. "Immobilized by the Middle Brook water from the north, personnel could do nothing to shore up the dike against the rising Raritan River on the south and by early evening the Raritan had raised the water level in the Plant to seven to eight feet. All services were lost."[10] Every structure at the facility was at least partially submerged. "From the air the 600-acre plant site looked like an industrial Venice, with up to seven feet of water swirling into and around the 150 buildings ... The rising waters lifted an almost-empty ammonia tank that was 60 feet high and 30 feet in diameter off its base. The tank floated upright, drifting about 500 yards," from building 78 to the eastern fence, where it came to rest, "between a box car and a loading station." Elsewhere, two railroad tank cars "near Bldg. 118, were hundreds of feet from the nearest track."[11] As the waters receded, rowboats that had replaced normal transport within the plant came to rest on railroad tracks. It took one month of drying out and restoration of essential services before 75 percent of production was back to normal.

The stored pigments made by the new computerized azo dye process contributed visibly to the scene. In recalling this Isaiah Von also concluded the story of their fate. "The bottom layers of the off-grade drums were weakened by exposure to water and caused the upper layers of drums to fall into the water. They floated throughout the plant. One manager, flying above the scene, said it looked like the plant had the measles." Von opines that this "would have been a golden opportunity to call it quits, take the insurance money and end the project." However, management did not give up and

> eagerly rebuilt everything and azo automation was off and running again. We used a system which was about half automation and half manual labor. Every once in awhile we operated at 100 percent manual so we could blend enough to fill orders. We collected lots of data comparing automation-assisted batches with normal hand-made batches, which clearly showed the damage inflicted by the automation, but nobody at the top was interested in seeing our data. No matter how hard we tried we could not make any improvements, because with individual bad batches we could not know whether the problems were caused by the computer or by the operator. This went on until 1973.
>
> How did it come to an end? In 1972, Cyanamid got a new president, Jim Affleck. He despised Ludden [head of pigments], so shortly after he took office Ludden was gone. It did not take much convincing to get his successor to drop the project. The cost to us was tremendous and undoubtedly weakened our business. I still think it is a good concept, although it was very premature.[12]

Other less-successful areas were fiber-reactive dyes, and the use of electrochromism, the production of color changes by application of electrical energy to dyes. The problem with certain Calcobond reactive dyes was that the way was blocked with patents of other corporations. American Cyanamid felt that it could not "get in on the chlorotriazines (CIBA) or the vinylsulfones (Hoechst)." However, in an attempt to exploit the triazine ring present in melamine, as Jay Leavitt recalls, "one of our chemists came up with the idea of using the methylolated melamine group from the textile chemical finishes." Unfortunately, the melamine-based products were no match for the competition. As for electrochromism,"the watch displays were too slow and the conductive electrolyte polymers weren't good enough."[13]

In 1970, Bound Brook plant manager George Hedden and manager of manufacturing Richard Phelps reported to OCD president Joseph Schmidlein. Paden continued to direct "Organic Chemicals Research and Development," assisted by Theodore Cooke, who also served as chairman of the editorial board of the AATCC publication *Textile Chemist and Colorist.* In the same year, Joan Gallagher was appointed manager of Information Services for the newly merged Bound Brook and Stamford libraries. Research Services for Paden's division were managed by S. M. Davis. In addition to laboratories, this unit included the Literature and Patents Technical Group, still headed by Paul Dreisbach, divided into Patent Liaison (M. T. Beacham, and J. H. Butler), Information Systems (Michael Kondas), and Library and Reference Services (Joan Gallagher, librarian, and three assistant librarians, including Marie Cline). Patent Liaison was made up of chemists who coordinated the preparation of records of invention with patent attorneys at Stamford. Warren Forster was technical coordinator of the Chemical Information Office, associated with the Business Office.

The Chemical Research Division

By 1972, the corporation's range of research interests had become so widely disparate, encompassing so many fields of inquiry, that a separate Chemical Research Division (CRD) was created. On September 1, 1972, the new division, directed by Jason M. Salsbury, former Calco textile resin chemist then based at Stamford but soon moving to Wayne, underwent a number of managerial changes. Those that affected Bound Brook included the appointment of Paden as assistant to Salsbury. Cooke moved to Stamford to become director of Scientific Services for the CRD. Guido Mino was appointed director of the Bound Brook "Research Laboratory."[14] The CRD controlled research at the OCD, the Industrial Chemicals Division, the Plastics and Resins Division, and elsewhere.

Those Bound Brook laboratories now under the control of the CRD incorporated certain activities that were closely linked to the new division, including Exploratory Research, still managed by Rauhut. In October, Paden and the Bound Brook CRD laboratories hosted colleagues from various divisions at a technical conference held at the Far Hills Inn, Somerville. Tellingly, the four main presentations said much about the direction in which American Cyanamid was moving. Rauhut spoke on phosphine derivatives; Laurence

Research and Development Directors and Managers, Organic Chemicals Division, Bound Brook, in July 1972 (shortly before creation of the Chemical Research Division)

Directors
Dr. Joseph H. Paden, director
Dr. Theodore F. Cooke Jr., assistant director
Managers
Dr. Stanley M. Davis, Research Services
Dr. William B. Hardy, Intermediates
Dr. J. H. Kaplan, Systems Analysis (computer control, process analysis and operations research, and technical computing and statistical analysis)
Dr. Erwin Klingsberg, research fellow, Exploratory Research
Dr. Neil M. Mackenzie, business manager
Dr. H. R. McCleary, Dyes and Textile Chemicals (Dyes and Textile Chemicals Departments were merged in 1964)
Dr. Guido Mino, Rubber Chemicals
Dr. William B. Prescott, Analytical
Dr. Michael M. Rauhut, Exploratory Research
G. L. Wiesner, Process Development and Research

Notes: Prescott received the B.T.C. from Lowell Textile Institute in 1939, and an M.S. in chemistry from Rutgers University in 1956. He was a member of the American Society for Testing Materials, Committee E-19, and had worked on color measurements with Stearns. Rauhut received the B.S. from the University of Nevada in 1952, and Ph.D. from the University of North Carolina in 1956. He began his career at American Cyanamid's Stamford laboratories in 1955, rising to the post of group leader, Central Research Division. He joined the OCD in 1969, and was appointed manager of Exploratory Research at Bound Brook in 1970. Hardy reported to Paden, and Davis reported to Cooke, from September 1968. Dr. Richard K. Madison was group leader, Exploratory Research. Dr. R. H. Ebel managed Refinery Chemicals R&D at Stamford, which included catalyst research, catalyst systems, and process development. Research Services included literature and patents, analysis, physical chemistry, hazards evaluation, and instruments.

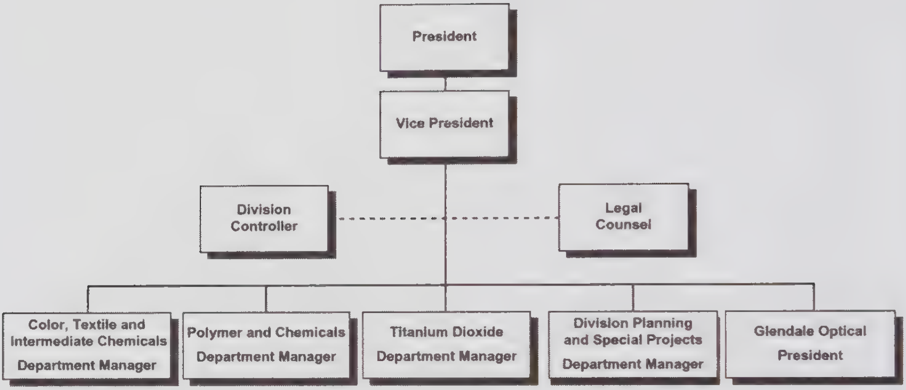
L. Williams, project manager, CRD, Stamford, on acrylamide polymers for unbleached kraft papermaking; Malcolm K. Orloff, CRD, Stamford, on the application of molecular orbital calculations to pharmacologically active molecules, and a new fluorescer; Martin J.

Weiss, Lederle Laboratories Division, on the recently discovered prostaglandins; and Cyril A. Kust, Agricultural Division, on phthalimides as plant-growth regulators.[15] Weiss, who received his Ph.D. from Duke University in 1949, joined the Bound Brook Pharmaceutical Research Department in 1950, and four years later was appointed group leader. In 1955 he was transferred to Lederle.

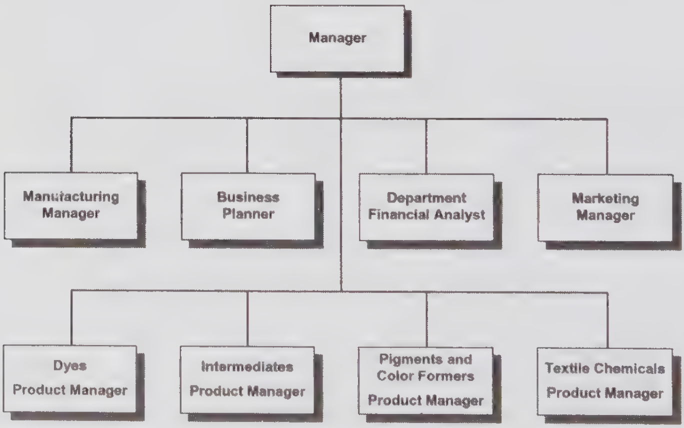
In December 1972, Ben H. Loper was appointed president of the OCD. His wide-ranging experience at American Cyanamid, including with the Bound Brook Dyes Department, provided appropriate background for the tough period ahead, following, in common with other chemical firms, a decade of loss of innovation and ever more stringent effluent-control requirements. Prior to becoming president of the OCD, Loper had been assistant general manager, Plastics and Resins Division, Wallingford (1964–67), and president of North American Cyanamid, Ltd (Cyanamid of Canada, Ltd) (1968–73).[16]

In 1973, Bound Brook's Research Services for Organic Chemicals Research and Development was extensively based on the use of instrumental methods, including microscopy and X-ray analysis. Thermal analysis was also important. The stabilities of dye intermediates were determined by differential thermal analysis and differential scanning colorimetry, while thermogravimetric analysis was used to study kinetics of polymer oxidation and decomposition. Effluent study was another active area, including gas chromatograph–mass spectrometer analysis of volatiles from effluent sludges, and investigation of an ammonia electrode for analysis. These were, in part, responses to new environmental regulations, and their enforcement.

Changes in organization, rationalization, and the new well-equipped research laboratories and process improvements at Bound Brook, could not alter the stark fact that in the 1970s the dye industry was entering a difficult period. The U.S. tariff system that since the 1930s had favored dyes made in America underwent considerable change within the framework of Kennedy Round trade negotiations. Protection of the domestic dye industry ceased, and this, along with growing problems related to environmental issues, caused several American firms to get out of manufacture after 1976. Moreover, in the wake of the 1973 oil embargo, American Cyanamid, in common with some other chemical firms, had found itself with heavy losses from its



American Cyanamid Organic Chemicals Division, general management, from 1974



Color, Textile and Intermediate Chemicals Department, Bound Brook, created in 1974 construction, land-development and real-estate ventures, started in 1970, and poor sales of consumer products. Even the medical side failed to contribute its usual 30 percent of total earnings. Little wonder then that Clifford Siverd, who was appointed American Cyanamid chairman in 1972, had "continued Cyanamid's shift away from an emphasis on chemical products, largely through a series of acquisitions," though even here there were failures.[17]

Adding to the conflicting scenarios from 1974 was a Justice Department price-fixing action, charging collusion among nine firms, including American Cyanamid, when dye prices were increased on March 1, 1971. Sales of dyes in the United States during 1971 totaled $480 million, of which $57 million represented imports. American Cyanamid and the other companies (DuPont; Verona Corp. of Union, New Jersey; Allied Chemical; American Color & Chemical Co. of Paterson, New Jersey; BASF Wyandotte of Michigan; CIBA-Geigy Corp.; Crompton & Knowles; and GAF) accounted for about $300 million of the U.S. sales. This was one of the most widely publicized occasions when American Cyanamid was accused of coordinating prices with other manufacturers. It was a further example of the difficulties facing manufacturers of dyes.

Modernization and Rehabilitation

Defying the trend in which most chemical sectors faced erosion of profits, sales of American Cyanamid agricultural products in the early 1970s remained brisk and were valuable contributors to the balance sheet. Many veterinary products and agricultural chemicals, including pesticides, sold through the Agricultural Division in Princeton, were reliant on Bound Brook, with the result that the role of the facility in the corporation's future appeared brighter than it had been for some years. During 1974–75, Ben Loper authorized preparation of a lengthy prospectus in support of improvements in the Bound Brook waste-treatment system, general rehabilitation, and process changes, in addition to certain shutdowns, replacements, and expansions. His introduction, addressed to the American Cyanamid Executive Committee, suggested ways for meeting the new objectives, in particular how installation of a massive and expensive tertiary wastewater-treatment plant would meet the requirements of a 1973 consent order. Serious issues concerning the future of the site were raised, particularly since a new phase of modernization had already commenced in the early 1970s (including a "multi-million dollar six-storey computer-controlled mechanized warehouse, honeycombed with 8,000 storage slots").

Meeting objectives required a review of the anticipated demand for products of the facility, which was responsible for "$181 million, or 10%, of American Cyanamid Company sales and $19.4 million, or 12.5%, of profits … Based on manufacturing costs, the plant produces about 55% Organic Chemicals products, 20% Agricultural products, 15% Organic Pigments, and 10% Lederle products. From 7 to 12% is shipped out of the country. The highly profitable Ag[ricultural] and Lederle pharmaceutical products represent about 45% of the sales and 55% of the profits and account for about 35% of the total pollution."[18]

Certainly, Bound Brook appeared to be a good candidate for future expansion:

> To evaluate the major commitment to the Bound Brook site that the effluent treatment facility represents, the viability of the plant itself, major future investments, and alternative courses of action had to be considered … The return on investment on plant output was 11.7% … The site represents a plant, property, and equipment [PP&E] investment of $133m or about 11% of total Cyanamid PP&E … Bound Brook is the headquarters for the Organic Chemicals Division and the Pigments Division and the Controller's Division. It supplies products to most other divisions with the most significant being the Agricultural, Cyanamid International, Cyanamid of Canada and Lederle Laboratories Divisions, which market almost one-third of the plant output (based on manufacturing cost).[19]

Available markets, labor, energy, water, and land all appeared to favor modernization and retention of the plant, which

> is well located in relation to customers and suppliers, with 40–50% of total U.S. manufacturing within the next-day truck delivery area. Truck, water, rail, and air transportation is superior to many other locations. Workers can be drawn from a large labor market. The labor relations climate is stable. The work force

is experienced. There is ready access to technical staff, on-site and at Wayne and Stamford. The supporting facilities have in-place capacity and could be enlarged easily for expansion. Because of the economies of scale, the energy utilization rate is high. Gas is short, but supplies of oil, the main energy source, are sound. Electricity is readily available, both purchased and generated at Bound Brook. Water is abundant. Open land is available for manufacturing expansion equal to 125% of existing occupied manufacturing areas.[20]

Many buildings, however, had deteriorated over the years, particularly those dating from around 1915, the 1930s, and 1940s. Older buildings were in poor states of repair, requiring replacement or extensive improvements. The bleak and uninviting working conditions, at least by 1970s standards, certainly did not help in attracting new staff to Bound Brook. "Although almost two thirds of the plant investment in dollars have been made in the last 10 years, some parts of the plant are reaching the end of their useful life. Rehabilitation projects can be anticipated from 1975 through 1985 at a cost of $20 to $30 million. Some will show self-justifying savings in reduced operating costs, others will be needed to sustain production in profitable products, and still others will involve office and laboratory upgrading."[21]

The earlier buildings and "many of the basic services installed during those periods are inconsistent with today's standards and technology ... A comprehensive study of the overall physical condition of the plant, including utilities, services, and operating and office buildings and laboratories, was completed in December 1974. A preliminary rehabilitation program has been developed for the Bound Brook Plant which will upgrade the facilities which are obsolete or deteriorated and will improve the working environment to an acceptable level for the labor market in which we compete."[22] Building 10, which dated from 1937, and building 40, erected in three stages in 1916, 1930, and 1935, housed most of the personnel concerned with administration. Two laboratories, dyes application and dyes development, occupied almost all the third floor in building 10.

As for waste treatment, three alternatives to installation of the tertiary waste-treatment system were considered. These were relocation elsewhere, treatment of effluent "at the source of pollution instead of at the end of the sewer network," or membership in a regional sewerage authority. All these were rejected in favor of continuation of production at Bound Brook, through upgrading of wastewater treatment by installation of the highly novel activated-carbon facility that treated the combined plant wastewaters.[23]

The Last Years of Dye and Pigment Making

During 1976–77, American Cyanamid's fertilizer business suffered a major downturn, and a new emphasis was placed on the colorant business. Attentive readers of *The Wall Street Journal*, *Chemical Marketing Reporter*, and *The Journal of Commerce* would have noticed occasional upbeat articles announcing the upgrading of Bound Brook and associated facilities, and plans for substantial increases in production, especially of pigments. At Bound Brook, a new $10 million Tobias acid plant, "the largest of its type in the world," would be based, according to Loper, on "new and unique technology," that is, continuous operation. Planning had commenced around 1970, as part of a program drawn up by a Dyes Modernization Task Force whose investigations covered intermediates, dyes, and pigments.

The Tobias acid (2-amino-1-naphthalenesulfonic acid) would be made from beta-naphthol (BN) supplied from a new plant at Willow Island, inaugurated in 1975, which made American Cyanamid the "world's largest producer" of this intermediate. The decision to introduce the new Tobias acid process was made only after alternative sources of supply were considered, including import of Polish-made acid. As part of rationalization, the Dyes and Textile Chemicals and Pigments Departments were merged during winter 1973–74 to create the Color, Textile and Intermediate Chemicals Department. BN and its derivatives, including Tobias acid and beta-oxynaphthoic acid (BON), the latter also made at Willow Island, "will be used by Cyanamid's Color, Textile and Intermediate Chemicals Department [at Bound Brook] to manufacture organic red pigments and dyes." These reds based on BN and its derivatives were the most successful of all azo pigments.

Marsden Vanderwaart was involved in the design of the new BN plant, working at Bound Brook as assistant to Al Joe in Process Engineering. After serving with the Engineering and Construction

Division (ECD), Vanderwaart had moved on to the Industrial Chemicals Division, and then, in 1967, to the Wallingford resins facility, before a short assignment at Bloomingdale Rubber Co., in Havre de Grace, Maryland. He was not keen to return to the ECD:

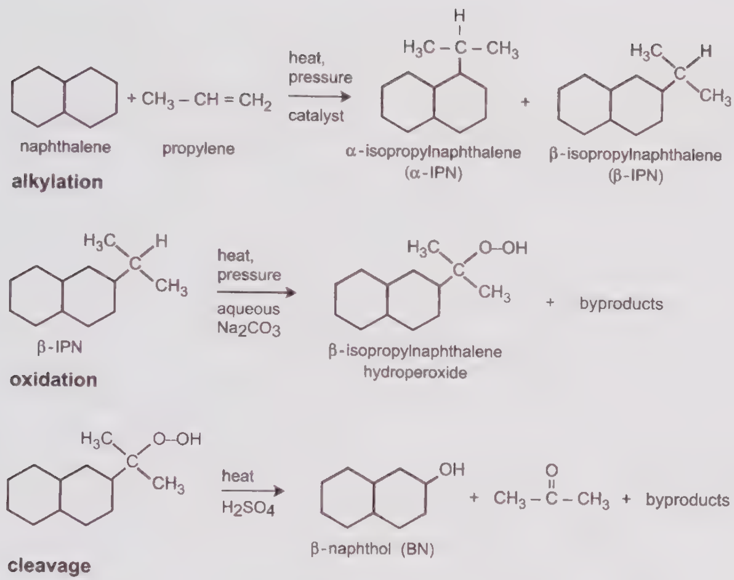
I had seen too much politics and self aggrandization when I was there before. Early in a project, one would make a suggestion, [and] ever after that, the effort was to prove that this was the thing to do and all efforts to really find the best solution went by the boards. At Bound Brook, I had two offers—to help George Wiesner in process development or to help Al Joe in process engineering. I chose the latter. These years, 1970 to 1977, were the most enjoyable of my career. By and large I was an independent consultant. I hunted up my own assignments, worked on them in my own way and reported them in my own way ... I had a few major assignments. First was economic evaluation of the beta-naphthol complex to be installed at Willow Island. The complex was to make beta-naphthol and several derivatives—R-salt and S-salt among them. I used the GE Time Share Computer with a teletype terminal at 6 characters a second. I had all the raw material usages, labor usages, equipment costs, sales forecasts, royalty payments and factors for allocated costs. I made cost sheets for each product ... My office wall was covered with sheets of print out. This was all prior to spreadsheets and was done in Basic. However, a single cost could change or a forecast could change and the results would be known maybe not immediately but shortly, at least by tomorrow. The accounting department threw up their hands at doing this task manually. For the computer was not subject to human error. This was quite an accomplishment for the time.[24]

Vanderwaart's other projects included the first stage in the design of a fixed-bed catalytic process for continuous alkylation of *p*-cresol and *p*-ethylphenol with isobutylene to afford mono-butyl-*p*-cresol (MBC) and mono-butyl-*p*-ethylphenol (MBEP), respectively. These projects involved the Central Engineering Department at Bound Brook and the Engineering and Construction Division at Wayne. However, the MBC and MBEP development work was not completed, since commercial considerations in 1980 dictated that the existing batch process satisfied the demands. This was not the case with BN and Tobias acid.

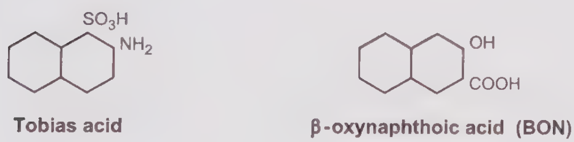
The new BN process, which commenced with alkylation of naphthalene, was intended to satisfy greatly increased demand for pigments, as distinct from dyes, used mainly in color printing on cartons and general packaging, in advertising material, and in newspapers, magazines, and other publications. Cyanamid planned a "50 percent increase in pigment production capacity to coincide with the additional captive supplies of BN and BON."[25] The latter each accounted for five azo pigments, nine of which were red and one brown, that were converted to various salts. Willow Island also manufactured the BN-derived intermediates Schaeffer's salt, and G-, R-, and S-salts, in addition to BON, for Bound Brook and for general sales. Two other important Bound Brook pigments were the phthalocyanine blues and greens, though not, as Isaiah Von explained, the green shade of blue that had been developed at Bound Brook.

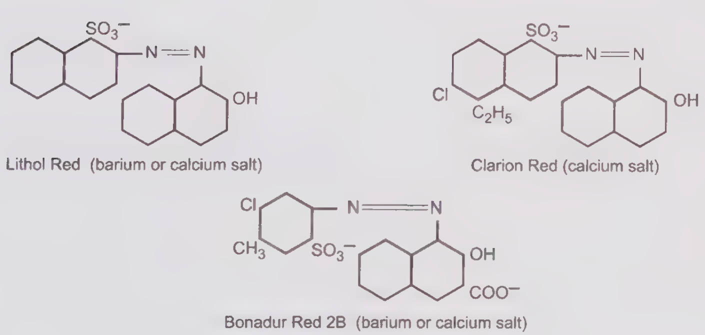
Von recalls that "considerably more than half of our pigment production was for the printing ink trade. The amounts made for paint and plastic were substantially less."[26] The BON-based azo pigments made at Bound Brook were marketed mostly as Bonadurs (from BON and "a little greater durability"). "In the BON list there was Bonadur Red 2B (C.I. Red 48, calcium and barium salts) and Lithol Rubine (C.I. Red 57)." The major BN products were Lithol Red (C.I. Red 49, calcium and barium salts), Red Lake C (C.I. Red 53, barium salt), and Clarion Red, the latter notable for the fact that it was "an ethylbenzene derivative instead of a toluene [methylbenzene] derivative ... a Calco invention that was quite successful. It was one of the few times, or perhaps the only time, that Dr. Lecher's approach to color research paid off." In addition to pigments, the OCD offered acid, basic, direct, fluorescent, mordant, solvent, sulfur, and vat dyes, made at Bound Brook, Damascus, Marietta, and Willow Island.

Investors and dye users were given the same optimistic message: "In anticipation of the pollution problems that have forced some companies to delete products from their line or to withdraw completely from the dyestuffs business, Cyanamid has invested over twenty million dollars in the most modern waste water treatment facility of its kind at Bound Brook, New Jersey." The corporation had recently approved an expenditure of $10 million in a new high-capacity semicontinuous nigrosine plant at Bound Brook. In total, $13 million was invested in the nigrosine process, operated with 4,000-gallon steel kettles at a pressure of 75 pounds per square inch. The major uses for nigrosines (soluble blacks 5, 7, and 26 in the



Simplified process chemistry for Willow Island β-naphthol (BN) process (1975)
Alkylation is accompanied by formation of diisopropylnaphthalene (DIPN) and higher alkylates. The process was designed to isomerize α-IPN to β-IPN, and convert DIPN into IPN.





Examples of azo pigments

Colour Index) were in phenol-type plastics (such as Bakelite), shoe polishes, and, after sulfonation, inks and black paper dyes. In the mid-1970s, there were no competitors in the United States, but there was one manufacturer in the United Kingdom and another in Japan. Bound Brook intended to double its output with the new process.

Around this time, in 1976, the DPA (diphenylamine) plant caught fire, and manufacture of this important chemical, used extensively in rubber products, ceased. The DPA plant had earlier been causing considerable trouble, following the changeover to a new catalyst. This was another assignment for Vanderwaart: "Tubes in the diphenyl amine fixed bed catalyst reactor were breaking on a regular basis. No cause could be found, but most blamed lax operator control in the hot regeneration cycle. This did not sit well with me. Finally I put two and two together. A change in catalyst had been made and the yield had increased significantly. This resulted in much higher ammonia concentrations. And in a Metal Handbook I read that ammonia was used to nitride certain steels and that these steels were brittle. We had samples analysed and inspected by consulting metallurgists and they confirmed. A change in steel composition eliminated this problem." DPA had been a major contributor to solid and tar waste loads, as was another intermediate, 4-NOX, or 4-nitro-*ortho*-xylene, required for the manufacture of the Agricultural Division's cotton and corn herbicide, known as Prowl, and introduced commercially in 1975. The 4-NOX was manufactured at Bound Brook from 1972–73, originally on a pilot-plant scale, until 1977, after which production was moved to the new Hannibal, Missouri, production site.[27]

Another large manufacturer of vat and azo dyes was Toms River Chemical Corporation at Toms River, in Orange County, New Jersey. It was opened as a vat-dye facility by CIBA of Switzerland in 1950, and expanded after 1960, when CIBA, Geigy, and Sandoz moved their jointly owned azo-dye operations there from Cincinnati. The Toms River and Bound Brook facilities had in common the fact that they were the only two dye-making factories in New Jersey that required special permits to discharge treated effluent to limited-flow receiving surface waters. Unlike the few small dye-making firms in New Jersey, they did not have permits to release wastewater to municipal sewerage systems.

In September 1977, the Toms River in-house journal, *TRC News*, summarized the plight of the American dye industry in an article headed "Dyestuffs: A Future?"

"Progress" has not been kind to the dyestuff industry. It's "breaking up that old gang of ours" that used to be our competition. DuPont is phasing out the vat dye business within the next year. GAF has its dye business for sale. Allied Chemical, which drastically reduced its line in the early 1970s, sold its plant in Buffalo, New York, last June 30. Young Aniline of Baltimore, Maryland, went out of business in the early 1970s. Governmental regulations in the area of pollution control had a lot to do with decisions of these companies to give up the business. While Toms River Chemical Corporation has committed itself to the continuation of the production of dyes and intermediates, there are drawbacks. The competition that remains is tough. Only one competitor [DuPont], which is phasing out of the vat dye business, pays the same high wages and offers the same quality employee benefits that our company does. Our new $15.5 million wastewater treatment plant, built to comply with government regulations, represents an outlay of capital that offers no direct return on investment. Our remaining competitors do not have environmental problems of the same magnitude as our own. Some smaller manufacturers in North [New] Jersey, for example, do not face the problem because they are permitted to discharge into a municipal sewerage system. TRC has an uphill struggle to remain as a competitor in the industry.[28]

In addition to environmental problems and difficulties created by tariff reductions on dyes, there was also a limit to what firms were prepared to spend on dye research and development. In 1978, Robert Kenneth Fourness, a prominent member of the British Society of Dyers and Colourists, explained clearly why dye invention had a restricted future. The cost of research to make what might only be minor improvements could never be recovered. Moreover, the market for vat dyes had come under attack from reactive dyes, while the quest for disperse dyes for polyester and acrylics had been satisfied. Fourness also drew attention to the fact that alternatives had been found for the cancer-causing intermediates beta-naphthylamine and benzidine, the former discontinued in the 1950s and the latter banned, or restricted, in most countries from 1964, though not in the United States until 1970.[29] One reason for changes to the Tobias acid process at Bound Brook had been to avoid beta-naphthylamine.

Japan was also making rapid headway as a major exporter of synthetic dyes (followed within a few years by Korea and China). During 1975–79, Japan's annual output grew more than 50 percent, to 131,987,000 lbs. In the same period, exports increased from 26 million lbs. to 40 million lbs. In 1980, several major Japanese producers obtained permission from their government's Fair Trade Commission to form a "rationalization" cartel to deal with oversupply.[30] A significant event as far as the American dye industry was concerned was the 1982 agreement between Japan's Mitsubishi and Atlantic Industries, a small dye maker of Nutley, New Jersey, whereby the latter firm sold Mitsubishi's anthraquinone vat dyes in the United States.[31] Eventually, competition from the Japanese began to squeeze the German manufacturers out of the U.S. market.

In the mid-1970s, profits from certain Bound Brook dyes appeared sufficient to justify new investments. Early in 1977, American Cyanamid announced that though there were earlier plans to close down the Catan aniline plant, it would remain in operation, while the nitrobenzene (MNB) plant would be modernized. As for the older colorants, many of 19th-century vintage, in 1974–79 the highest value sales were achieved with solvent dyes, followed, successively, by acid, basic, direct, disperse, and modified basic dyes.

Vanderwaart, James B. Trecek, and Alexanderson were responsible for the improved MNB process during 1974-77. Vanderwaart recorded:

> We did laboratory batch nitrations and determined the rate of nitration ... We made a math model of a series of continuous stirred reactors. We made the heat and material balances around each piece of equipment and put it all together in a program. And then we could visualize how the plant would run under hundreds of different conditions. The best of these we picked out for the design of the plant. Some of the experimental work was done at Bound Brook and some was done by Canadian Industries Co. in a small town outside Montreal. Chemetics, in Vancouver, B.C., was the engineering company. They were a subsiduary of CIC. The plant was built and ran according to expectations. Chemetics built at least one more plant and Cyanamid enjoyed a royalty income long after Alex and I had retired.

Robert F. Bann, a specialist in azo and triphenylmethane dyes, managed production of dyes and intermediates at Bound Brook, prior to becoming, during 1973–76, general superintendent of dyes.[32] An indication of both the range and scale of dye-making operations in 1976 is given by production figures for the first ten months of the same year: Bismarck brown (azo dye), 64,269 lbs.; chrysoidine (azo dye), ca. 173,000 lbs.; fuchsine (basic dye), 95,717 lbs.; methyl violet (basic dye), ca. 800,000 lbs.; methylene blue (basic dye), 53,880 lbs.; various nigrosines, ca. 3,700,000 lbs.; and spirit blues (basic dyes), ca. 94,000 lbs. More modern, insofar as it dated from 1920, was Jade Green, the largest-volume vat dye, of which 301,442 lbs. were produced.[33] Among the intermediates made at Bound Brook were *ortho*-benzoylbenzoic acid and chlorobenzoyl benzoic acid, and, derived from them, the anthraquinone derivatives essential to vat-dye manufacture.

The considerable production of vat dyes was encouraged by the fact that the "U.S. use of vats was greater than that in Europe, due to greater fastness properties. It was certainly not due to greater shade variation or brightness, since the vat colors tend to be subdued in shade. Possibly there was greater use of cotton. Of course, at least since World War II the military used mainly vats."[34] Other products made from aromatic intermediates included sodium MBT and MBTS rubber accelerators, of which around 13 to 18 million lbs. were manufactured annually in the Rubber Chemicals Department during the 1960s, and until the late 1970s. A newer zinc derivative of MBT, known as ZMBT, was a useful accelerator, particularly after a wettable version for latex was introduced in the mid-1960s.

Any remaining optimism, however, did not survive very long. Gerard (Jerry) Forlenza, who replaced Loper as president of the OCD in 1977, commissioned outside dye consultants to advise on whether or not dye making at Bound Brook "stood a chance." While the experts argued strongly for continuation, Forlenza was not convinced. At that time, it was clear that: "Whatever you do, the other guy will undercut."[35] The market rules of survival in the face of stiff competition had earlier invited abuses such as price-fixing among dye makers, which, as Forlenza points out, reflected the difficulty of the business. Nevertheless, the OCD decided to give dyes and pigments a "couple of shots, put money into BN," and invest in continuous, automated processes in an attempt to lower costs. Decision making was difficult, and had to take into account many variables and questions, not the least of which was how to absorb overheads if departments were closed down. The outcomes were sometimes tough and painful, particularly when "very good, serious, dedicated individuals" who had spent their entire careers in the colorant business had to accept the fact that dyes, the legacy business, were just too competitive, and "not where we want to put our money."[36] When Forlenza left Cyanamid in 1979, dye and pigment sales were still healthy, though profits were not, nor were the new processes.

Two years earlier, in 1977, Vanderwaart left Bound Brook "on a happy note." At his retirement party, he brought along items that revived decades of memories of hectic, even if not always successful, technical activities: "I had the bolt from the phthalic acid feed drive in AQ [anthraquinone]. I had the screw jack that Carl Mensing had made when he was in college. I had a rubber stamp from the early days of the recording spectrophotometer that printed 'APPROXIMATE DATA ONLY.' I had a book retrieved from the Physics Lab. storeroom. It had page after page of the total selling price, giving the unit sales price across the top and the volume of the order down the side."

Failed Process Modernization

Despite the belief during the mid-1970s that process modernization and improved waste treatment would ensure continuation of Bound Brook well into the 21st century, there was during 1980–81 a rapid reversal of policy, especially after the new Tobias acid and nigrosine plants did not come up to expectations. Isaiah Von, who, as head of pigments manufacturing, had fought hard against the new Tobias acid unit, which went onstream in 1979, explains why the modernization failed, and contributed to the rapid demise of Bound Brook:

> The new Tobias acid plant never operated in a commercially satisfactory manner. Its failure was the straw that broke the camel's back and led to the shutdown of the organic pigments manufacturing department ... The corporate management always thought that the way to process modernization was through automation or development of continuous processes. The existing Tobias acid plant which was under the responsibility of the organic pigments manufacturing department (as were several other organic pigments inter-

mediates) was a perfectly good batch operation, which had been honed to near maximum performance. The management decided to replace it with a continuous operation, which, given the complexity of the process and the volume involved, was clearly inappropriate. I objected bitterly but lost.

The problems were compounded when an operator of the Tobias acid plant was killed following an explosion that took place in 1981. The unit was immediately shut down so that the cause could be investigated.[37] Willow Island's BN production, on which Bound Brook was dependent for its Tobias acid and azo pigments, was also highly problematic. How could failure follow so many successes?

These modernization ventures were indirectly the outcomes of proposals that came from outside of American Cyanamid. From the early 1960s, in the wake of difficult trading conditions, the firm's business strategy had relied strongly on the advice of the consultancy firm Booz-Allen & Hamilton, described by *Time* in 1959 as the "company doctors." The advice must have seemed reasonable at the time, since from the 1950s this firm had a reputation as a leading consultant for the chemical industry. A number of recommendations were adopted, particularly regarding increased exploitation of existing lines of business. This, it must have seemed, was far less risky than massive new investment in R&D, which had produced little in the way of useful innovations. All dyestuff R&D was discontinued in 1971, and Bound Brook research laboratory personnel were cut back. Certainly it was fully in accord with widespread received opinion that recommended process and quality improvements rather than new research campaigns. Von explains that he was "told by one of the OCD president's that the motivation for the new plants was this. In the early 1970s Cyanamid hired Booz-Allen & Hamilton, a prominent consulting firm, then and now, on the future course for OCD. The advice that came back was to increase world market share of those products where we were dominant in the United States through modernized plants using new or improved technology. This accounts for the beta-naphthol and nigrosine fiascos." The technical reasons for the beta-naphthol "fiasco," Von opines, were as follows.

Beta-naphthol [BN] had been made at Bound Brook for a great many years and the reaction conditions had been developed to a fine point. Yields were high and quality was excellent. Capacity was about 20,000,000 lbs. per year, and it was desired to increase production. It was decided to build a new plant [at Willow Island] with continuous operation. The old process was straightforward sulfonation of naphthalene followed by hydrolysis under alkaline conditions. Our development group decided to go with a different reaction, presumably because it was better suited for continuous processing. This process was analogous to the commercial process for phenol which involves the oxidation of cumene to yield phenol and acetone. So the new BN process involved reaction of naphthalene with propylene to form isopropylnaphthalene which was then converted to BN and acetone. However this process involved a complication that was not present in the phenol process. With naphthalene two isomers can and do form and these must be separated. Difficulty with this step resulted in quality problems [due to the presence of] by-products. The major use for BN at Bound Brook was for azo pigments. For consistent quality azos you need consistent quality BN [as well as other intermediates]. I spent many hours on the phone with Willow Island personnel going over their BN quality results, lot by lot, to select suitable material for our use. This was difficult because analyses did not involve batches but cuts from the continuous BN stream, so one was never sure what the analyses represented. Another disadvantage: the new process required some very high temperatures which required a lot of energy consumption. When the new plant was brought on line it was also the time of the Arab oil embargo which very substantially increased the costs.

Instead of turning to Von and others with years of production experience for counsel on the chemistry of the process at an early stage, the designers of the plant, driven by the technological imperative of continuous processing, paid scant attention to interferences from unwanted products. It was a situation far removed from the time that Vanderwaart at his job interview in 1940 alarmed Hans Lecher by declaring: "After the chemistry is worked out, I would like to help design the plant." The chemistry of the new BN process had not been worked out. The nigrosine problem at Bound Brook was a little different.

Nigrosine is an empirical product, that is, it is a mixture of components not all of whose compositions are known. It was made by batch process for many years at Bound Brook and its quality was an industry standard. The reaction conditions of the semi-continuous process were not exactly the same as for the batch process, so therefore the quality was not exactly the same. In fact a lot of product had the habit of self-igniting on standing. Nigrosine drums were stored for periods of time to check whether they would ignite or not … at one time, there were so many drums under scrutiny that a large tent was rented to store them in. This project was also the victim of bad sales forecasting. At the time, we were making about 4,000,000 lbs. per year. Based on forecasts the plant was sized at 12,000,000 lbs. This [greatly increased capacity] meant that the plant would have to start up and shut down several times during the year. This is not so easy to do with continuous processes. Further, the usage of nigrosine in the country dropped. Finally a Japanese company built a small plant in Newark, N.J., which satisfied the market.

Most of these problems, including dealings with the New Jersey Department of Environmental Protection, were confronted by Bound Brook plant manager Eldon Knape. Isaiah Von remembers that Knape managed the facility "at or near its end. In his office, his desk was placed on a platform that was about 6 or 8 inches high. In front of his desk he had a low slung couch whose cushions were about one foot off the floor and was all that was available for visitors to sit on … when I went in to see him, I couldn't help but look up to him."

Among the other products still made at Bound Brook was Cyanacryl elastomer, used mainly for tire yarn. In January 1979, at the height of a labor strike that began the previous month, the high-temperature rubber elastomer shop, a section of the Rubber Chemicals Department, was turning out record amounts, often in excess of 20,000 lbs. daily, according to an impromptu newsletter, "What's Up," published "for the duration" for the benefit of those still at work. It bemoaned the fact that: "Nothing could be better than to wake up at dawning and come here and have things back to normal in the morning!"[38] By this time, the *Bound Brook Diamond* had just been renamed the *OCD Diamond*, a portent of what was soon to follow.

A Final Glimpse

In 1980, American Cyanamid made a business decision to shut down the entire Bound Brook dye-making operation. It also withdrew from the tire-yarn business. Work on the modernized nitrobenzene plant was stopped, and production of aniline ceased. Certain laboratory projects were continued as part of a Chemical Research Division program, particularly on plastics additives, directed by Bill Hardy. In that year William Lee Berry, president of the Formica Division, and former Bound Brook pigment chemist, was appointed president of the OCD.[39] It was under his presidency that organic pigment production at Bound Brook came to an end during 1981–82. Von explains: "Pigments manufacture lasted until 1981 for phthalocyanines and early 1982 for azos. All the pigments technology was sold to the Sun Chemical Corp., which became the biggest organic pigments manufacturer in the U.S. The reason the azos lasted a little longer was that they still had some hope of making the Tobias acid plant work. When they threw in the towel on Tobias everything [including rubber accelerators] was shut down except for pharmaceuticals." Until 1984, there were several attempts to dispose of the factory to other dye manufacturers, including Toms River, though these met with no success. Production of the Pigment Division's chrome pigments at Willow Island, including the former United Color & Pigment products, ceased in 1980.

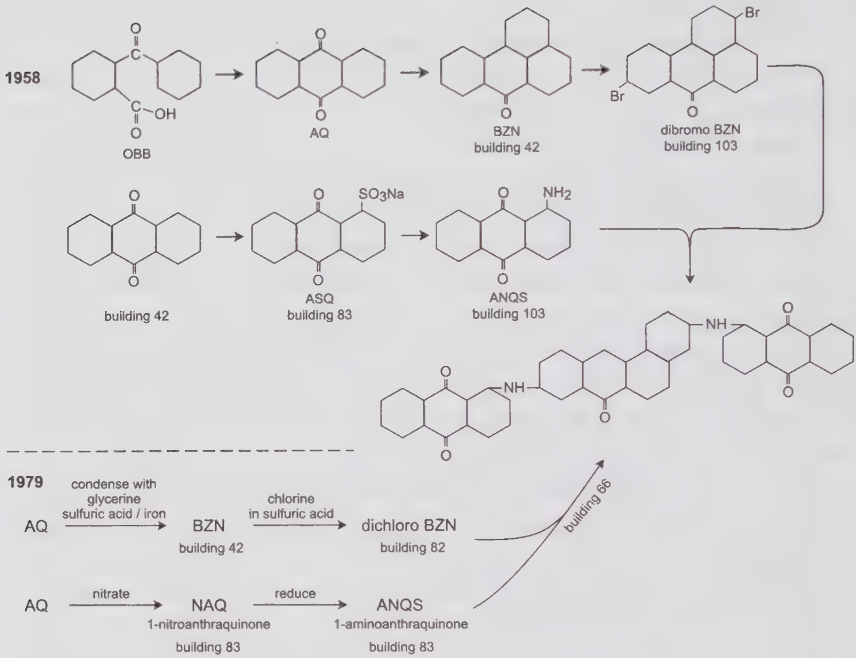
It is from accounts of Isaiah Von and others that we get the clearest impression of the last days of dye manufacture at Bound Brook. They provide us with a guided tour through the now almost-lost world of dye manufacture as it was practiced in America during the 20th century. Thus a visitor to the facility in the spring of 1978 would have found around 2,500 employees at work, including in azo building no. 43, the aniline plant, the nigrosine plant, then undergoing modernization, the automated warehouse, and the 1930s vat-dye buildings. Some workers were engaged in the erection of the new Tobias acid unit. Colorants were manufactured in eight buildings. One building was used for wet- and dry-blend finishing of vat, spirit, acid, and direct dyes. It was filled with mills, blenders, sand grinders, pebble mills, stainless-steel spinners, and blending tanks, and included packing facilities. Bound Brook continued to use mainly conventional kettle operations right till the end, as well as the traditional batch filter presses, and cone and V-blenders.

Two buildings, the adjoining nos. 43 and 63, were used for the manufacture of, predominantly, azo, direct, and oil colors as well as some spirit-soluble dyes. Typical equipment consisted of Haveg (a phenol-formaldehyde resin introduced in the 1930s), or wood, diazotization tubs, rubber- or brick-lined steel coupling tubs, and filter presses of either wood or polypropylene.[40] The lack of investment in, and run-down state of, colorant manufacture was apparent from the contents of building 63, which contained many tubs and kettles, mostly out of service, an experimental spray drier, and an inoperable phosgenation unit.

Vat dyes and their intermediates were made in five buildings, nos. 42, 66, 82, 83, and 103, some of which were about a half-century old. The equipment included glass-lined and mild-steel kettles, some with pressure capability; drowning tubs; and wood, steel, and polypropylene filter presses. The presscakes were dried mainly in tray dryers. Several products for pigments were also produced in buildings 83 and 103. In addition, building 42 processed some azo-dye intermediates. It was, as Von recalls, "filled mainly with equipment obtained from companies that Calco purchased. The other vat buildings were engineered by Calco people ... Some products made were not related to vats. This was especially true beginning in the 1960s when demand for vats started to decrease. The vat manufacturing department contained the most versatile equipment next to that of Pharmaceuticals, where only drugs were allowed to be made."

Derelict 5-nitro-*para*-toluenesulfonic acid (PNTS) and 4,4′-dinitro-2,2′-stilbenesulfonic acid (DNS) equipment reminded Von of "one of our triumphs. We developed a process whereby PNT [*para*-nitrotoluene] is sulfonated [to PNTS] by SO_3 gas, which is pretty hard to do and had to be done in specially designed continuous reactors." Almost 1.5 million lbs. of PNTS were made at Bound Brook during the first six months of 1976, after which production was abandoned. Von observes that "some of our most important process improvements were developed in our [Department G] lab. One is the formation of anthrimides without use of solvents in a ball mill. This helped to lower the costs of Olive Green B and Olive T [from condensation of dibromo-, or dichloro-, benzanthrone with 1-aminoanthraquinone] substantially. Another was the Jade Green process which used a minimum number of process steps."

At Bound Brook there were looming environmental problems, including disputes with state authorities over the quality of effluent discharged to the Raritan River from the new advanced wastewater-



Vat Olive T (Vat Black 25) (Bound Brook abbreviations)

treatment plant. In December 1982, the site was listed on the Environmental Protection Agency's National Priorities List of contaminated sites (in response to the Comprehensive Environmental Response, Compensation, and Liability—or Superfund—Act, 1980). No doubt part of the difficulty connected with Bound Brook was its location in New Jersey, where the environmental laws were among the strictest in the country.[41]

Von has the final word on why the closure of dyes and pigments was so sudden:

I certainly believe that the failure of the Tobias plant as well as the disappointing results of other major projects hastened the closing of the Bound Brook plant. OCD spent a lot of money on new projects in the '70s (with advice of Booz-Allen & Hamilton) and got very little for it. One reason was the management's infatuation with continuous processing without understanding when it is useful and when it is not. The main value of continuous processing is that raw materials can be added to the reaction and the product isolated through mechanical means. Thus in large-scale operations, continuous operation is extremely valuable. A drawback is that continuous process reaction conditions must be highly developed and controlled relative to batch processes. This means higher development costs and instrumentation. It also means large volume production. Most of the manufacture at Bound Brook was fine chemicals with relatively low production rates and hence mostly batch processes.

The failure of modernization at Bound Brook, closely connected to problems with Willow Island's beta-naphthol, did not in any way impact on American Cyanamid's new move to the high added-value pharmaceutical products. In all likelihood, it probably accelerated the trend. At the end of 1984, just 450 employees remained at work in what had become mainly a satellite of the Lederle Division. Research for the Polymer Products Division, including light stabilization of polypropylene fibers, and for Glendale, was still carried out at this time.[42]

In 1985, president George Sella sold off the Formica Corporation and the titanium dioxide units, ostensibly because they were too cyclical, but also in the case of Formica because of lack of investment. Fertilizers were dropped by American Cyanamid in 1986, as were most consumer products during 1987–90. From 1986, the plant manager at Bound Brook was Lederle pharmaceutical chemist Karel Francis Bernady.[43] American Cyanamid dyestuff technology, which included processes worked at Marietta, the former American Home Products unit, and the last American Cyanamid dye-making facility, was sold to BASF Corporation, the North American affiliate of BASF AG, in 1988.[44]

By the end of the decade, when American Cyanamid operated as three business groups—pharmaceutical, agricultural, and chemicals—the pharmaceutical and agricultural businesses represented 57 percent of sales, and 89 percent of total operating earnings.[45] Much of the remaining traditional chemicals business, including within the OCD, was shifted to what was informally known as 3C, that became the subsidiary Cytec Industries, established in 1992, with worldwide headquarters in Paterson, New Jersey. Also in 1992, Glendale Protective Technologies was sold off, and the Niagara Falls plant closed, following decline in the demand for calcium carbide made there for desulfurizing agents, used mainly in the steel industry. In 1993, the

American Cyanamid board of directors approved the spin-off of Cytec. Each American Cyanamid stockholder received one Cytec share for every ten shares held.

According to Darryl D. Fry, president and chief executive officer of Cytec: "Cyanamid decided it wanted to be a life sciences company in the 1980s, so it emphasized its crop protection and pharmaceuticals businesses." When interviewed by *Chemical and Engineering News*, he characterized American Cyanamid "as a large corporation with layer upon layer of management. For instance, he says Cyanamid's chemical operations 'had five divisions, with division presidents, and vice presidents, and with all the structures that go along with that.'"[46]

In 1994, American Cyanamid, or at least its two remaining parts, Lederle and the Princeton-based Agricultural Division, was purchased by American Home Products of Madison, New Jersey, for $9.7 billion. Six years later, in March 2000, the American Cyanamid name, with its agrochemicals business, was sold for $3.8 billion, plus an assumption of $100 million in debt, to BASF AG, which beat rival bidders Bayer, DuPont, Dow, and Sumitomo. John R. Stafford, chairman, president, and chief executive officer of American Home Products, explained that though "the Agricultural Products division has made significant contributions to AHP … the sale of Cyanamid reflects AHP's strategy to focus on pharmaceutical, biopharmaceutical, consumer health care and animal health products businesses."[47]

In May 2001, BASF, in the midst of expanding its crop chemicals business through acquisitions, announced that it would close its "Agro Research Center" and discontinue R&D activities at Princeton, New Jersey, in 2002.[48] It was the end for American Cyanamid.

Chapter 8

Research and Development at Bound Brook: 1950–1980

> "As I go through laboratories and plants and see more and more people with private offices or desks and fewer and fewer people at the work benches, I always wonder how long it will be before something will have to be done about it."—Milton C. Whitaker, American Cyanamid, New York, to Elmore H. Northey, Stamford, April 20, 1955.[1]

With Bound Brook research and development (R&D) as its central theme, this chapter deals mainly with questions concerning the post-1960 failures of American Cyanamid's strategies in chemical research, what lay behind the inability to take risks, and the apparent demise in insight. This contrasts sharply with the previous two decades, during which time the Bound Brook research laboratories, alone or in collaboration mainly with Stamford or Pearl River (Lederle), came up with many commercially successful products, including dyestuffs, amino plastics, sulfa, or wonder, drugs, and other pharmaceuticals. Several started out as the transfer of foreign ideas, including through licensing arrangements and joint ventures, turned into completely new products that enabled American Cyanamid to enter, and sometimes dominate, new sectors.

In the decade or so after 1945, competition and new technical challenges encouraged progress in dye invention that led to novel versions of direct, sulfur, and vat dyes. They resulted from diligent scouring of the patent literature and postwar FIAT and BIOS reports, or from analysis of competitors' products. While not exactly spectacular, new finishes in connection with fast dyeing of cellulose were also developed, as were modified resins with specific properties that permitted a wide variety of textile applications, such as aids to dyeing, and prevention of fading, wrinkling, and creasing, the retention of pleats, and water resistance. No less important were modified dyes suited to coloration of acrylic and other synthetic fibers, including complex disperse dyes, optical bleaches, and products that prevented the degradation of plastics by ultraviolet light. Process improvements were often the outcomes of research in production departments, rather than in the Bound Brook Research Department (from 1954 part of the Research Division), which dealt with more fundamental issues.

What is clear is that by the late 1950s, after a number of mainly I.G. Farben discoveries and inventions had been exploited, there were few new ideas from which to draw inspiration. Technology transfer in mainstream organic chemistry, of the sort that underscored the emergence of American Cyanamid as a major innovator, had come to a near standstill not long after the Research Division was created. Organization of R&D and research policies now began to undulate as control passed to-and-fro between central and local managements and became increasingly accountable to marketing departments.

In an effort to promote original discovery rather than innovations based on imitation or over-reliance on core technologies, the management introduced a policy of "free-research-time," soon referred to as free-time research, in which research scientists were allowed to devote 10 percent of their time to topics that interested them.[2] This meant they could explore new areas without being restrained by the pressures of the marketing departments that took over from research managers the work of defining goals and objectives, both short- and long-term, for R&D personnel.

Decline in Innovation

Nevertheless, it was difficult to prescribe both stimulation and new directions even for free-time research. As for existing lines of inquiry, there was little that seemed to justify the cost of the investment, as vat dyes demonstrated. In 1956, when Bound Brook's Fred Fordemwalt described the history of fast dyes at the Perkin Centennial celebrations in New York, he observed that research involving vat dyes still seemed to hold out considerable promise. By the end of the 1960s, however, the most outstanding dyeing difficulties had been overcome, and the future of vat-dye innovations was threatened by the success of fiber-reactive dyes.

Industrial polymer science, which had been exploited on many fronts elsewhere, had also passed its peak. The combination of American Cyanamid expertise, manpower, and capital, and the extensive facilities, including the Geneva research institute, a company-wide Research Coordinating Committee, layers of organization, and research and development departments, afforded no new radical innovations. Industrial research, in any case, had lost much of its appeal, as even DuPont discovered. There, "exploratory research" came under careful scrutiny and, in the face of declining cash reserves, emphasis was placed on securing markets for existing product lines. When in 1973 a lawyer became head of DuPont, the company's researchers became despondent. Budgets and staff were cut. The research effort improved only in 1979, when a move toward life sciences was promoted by Edward G. Jefferson, the new research executive.[3]

At Bound Brook, as at DuPont, free-time exploratory research attracted little interest, and was dropped in 1976. In part this was a result of cuts in research budgets, demoralization following dismissals, particularly in 1971, and lack of status afforded to bench chemists.[4] Salaries of scientists in particular were poor, as was highlighted in a case concerning illegal sale of industrial secrets. American Cyanamid dragged two Lederle employees into court, where they were accused of theft of formulas and microorganisms. The culprits were found guilty and sent to prison. Judge Mentzer, "in passing the sentences, said that American Cyanamid had spent a large sum of money to bring these men to trial. He added that the theft might not have happened had that money been used to upgrade the salaries of its chemists. The salaries, according to Judge Mentzer, were no higher than those of men two years out of law school."[5] The reputation of industrial research also suffered from a poor image among academic scientists, who saw it as a pursuit constrained and controlled mainly by short-term profit motives.[6] After the mid-1970s at Bound Brook there was a profound sense of betrayal, both intellectually and emotionally, among some scientists.

In considering Bound Brook as a quite general case study, we come some way toward understanding much about the halt in innovative activity, and why there was no reversal, at least in the traditional chemical sectors. This poses questions such as: Did Cyanamid become afflicted with the emergence of a management culture that appeared to restrain or repress the generation of ideas? Was complacency encouraged, for example, by easy profits from Lederle's involvement in a broad antibiotic cartel, price-fixing among dye manufacturers, and the continuing demand for mature products such as melamine, used in Formica? Was senior management overly high-handed in its attitude toward experienced and often high-caliber research and development chemists? Or was Cyanamid just another victim of an industry-wide problem of lack of creativity, a "housing folly" (the real-estate venture), and "some very shoddy market research in the 1950s and 1960s"?[7]

Peter Morris, in his *The American Synthetic Rubber Research Program,* concludes that the free market and open competition provided the optimal environment for innovation among "companies—above an approximate threshold size—with significant research and development programs."[8] Such a situation approximates to an oligarchy, in which large firms, relying on the process of routine innovation, compete in similar markets. American Cyanamid certainly came into this category, as did DuPont and other major firms—several outside the United States. Despite this, they were incapable of bringing about notable and altogether radical chemical innovations, particularly during the 1970s. Of over sixty important new products introduced between 1930 and the early 1980s, one-third were developed in the 1950s and 1960s, and only three after 1970. In petrochemicals alone, there were nine new innovations between 1961 and 1973, and just two between 1973 and 1982.

Using the example of DuPont, historian John Kenly Smith Jr. has suggested that the problem was that the new corporate-level organizations were unable to formulate research strategies: "Without a new strategy, the 1960s innovation initiative at DuPont failed to establish new trajectories or traditions. Everybody worked within the older regimes and the results were predictable—a host of high performance polymers that cost a fortune to commercialize and had difficulty finding profitable niches."[9] Fred Aftalion's perspective was similar to that of many in the chemical industry: "Likewise the assumption that the fruits of research would be proportionate to the funds devoted to the sector was totally invalidated, for never had the world's chemical industry spent so much money in *research and development* to so little avail."[10] Was this slowdown in innovation a sign of industrial maturity? Had the U.S. chemical industry really reached its inventive zenith when it came to developing profitable products along traditional lines? If this was so, then what of the future?

Such complex questions deserve close scrutiny, and there are no complete answers. What is obvious is that the international chemical companies survived, and even flourished, though many changed direction and merged or split up in the 1990s. Long-familiar names disappeared or were sidelined in this process, including CIBA, Geigy, Sandoz, and Hoechst, or were relegated to specialties, including the remnants of ICI and American Cyanamid.

When it was realized at American Cyanamid in the 1960s that new inventions were not forthcoming, the strategy based on recommendations from the consultancy firm Booz-Allen & Hamilton was to explore novel ways of applying existing products. At Bound Brook, the development of different markets was discussed at technical lunch sessions, and new ideas were shared among 136 members of staff. The proposals included garden, domestic, and consumer products, and educational kits.[11] Many employees were appalled at the direction the corporation was taking. Resources that might have been concentrated in scientific and technological breakthroughs appeared to be diverted into consumer marketing and, later, construction activities and real-estate development. There was, however, another way of harnessing the technological and scientific skills, the life sciences.

In retrospect, we can see that in the case of American Cyanamid, the foundations of the life-sciences company that it would become from around 1980 started with the 1929 acquisition of Calco and Lederle, and, a few years later, marriage of their interests through coal-tar derivatives and sulfa drugs.[12] This was a brilliant stroke on the part of William Bell, though even around 1930, while gathering strength through acquisitions and diversity, he could hardly have seen where it would lead. Certainly innovations in pharmaceuticals during the 1930s were more akin to dye discovery than to anything remotely connected with the modern "life science industry." This does, however, demonstrate the importance of the dye industry to the emergence of the pharmaceutical–life sciences industry. Thus the attack on disease began with the syntheses of numerous compounds, often belonging to the same or similar classes. There was little or no inkling as to how a particular compound might exhibit its curative action. Testing was a hit-and-miss affair, based on laborious and time-consuming screening techniques of newly synthesized compounds, at least until Roblin and Paul H. Bell at Stamford in the early 1940s established a promising relationship between acid dissociation constants and activity in sulfa drugs.

Erwin Klingsberg

At American Cyanamid, the same arduous discovery process was also applied to agricultural products, particularly plant-protection chemicals. In the early 1950s, for example, William B. Hardy at Bound Brook and Kenneth G. Nolan at Stamford investigated fungicidal compositions containing aryldihalotriazines, some based on dye intermediates. Later, Erwin Klingsberg's pyrazolium salt synthesized at Bound Brook became the Agricultural Division's wild-oat herbicide Avenge (difenzoquat), first marketed outside the United States in 1973. Klingsberg's compound was a heterocycle, a ring of atoms containing carbon and at least one other element, in this case a novel nitrogen-heterocycle.[13] It is Klingsberg's career, and material from his personal archival collection, that drives much of this chapter, and contributes to other chapters. Extensive quotations from correspondence between those involved in controlling and undertaking research make the case for the alleged inadequacy, or otherwise, of American Cyanamid R&D during the 1970s.

Erwin Klingsberg was born in 1921. As a schoolboy he had "been mad about chemistry." He gained his B.S. at the University of Pennsylvania in 1941, where an interest in organic chemistry, particularly heterocycles, was kindled by the "marvelous lectures" of Professor Ernest C. Wagner. Klingsberg's doctoral studies were completed at the University of Rochester in 1944 under Donald S. Tarbell (also a noted historian of chemistry) and W. D. McPhee. How he got there is not without interest.

In the spring of 1941, I was a senior at the University of Pennsylvania, and was told by Professor E. C. Wagner that there was an opening at the graduate school of the University of Rochester that might be available to me if I wanted it. At the time I wasn't quite sure how to find Rochester on the map ... As I learned later, I was the beneficiary of the program undertaken by Professor [Arthur A.] Noyes to transform and modernize the U of R chemistry department. Years later Professor Tarbell told me that early in 1941 letters had been sent all over the country announcing the availability of fellowships and assistantships at the U of R and these letters produced exactly one recruit–me ... The war of course changed everything ... I participated under Professor Tarbell's supervision on [the detection and elimination of chemical warfare agents]; it introduced me to the publications of R[obert] Wizinger ... whom I met years later at the University of Basel ... We shared an interest at that time in sulfur heterocycles.[14]

After the war, according to Klingsberg, most of the Rochester graduates entered into industry.

I myself spent two years at the Schering Corporation, where I met the chemist who became, and remained, my wife. At Schering I worked on pyridine chemistry for the first time, and rather rashly offered my assistance to Professor Tarbell, who was writing a monograph on the subject. He accepted my offer but later thought better of the whole business. Having by that time reached the point of no return, I divided the enormous subject matter into 16 chapters and managed to recruit authors for all of them. After many vicissitudes the result saw the light of day in 1960–64 as a four-volume treatise under the Wiley-Interscience imprint. The reviews were friendly and I flatter myself that these volumes still have some utility.[15]

Klingsberg's interest in heterocycles paid great dividends at Bound Brook. In the 1950s, DuPont introduced one of the last vat-dye developments, a red oxadiazole dye, a heterocycle in which one oxygen and two nitrogens were present in the ring that bridged two anthraquinone moities. Klingsberg followed this up with a study of triazole anthraquinone chemistry. Then he moved on to sulfur heterocycles. Jay Leavitt recalls that Professor Fausto Ramirez of the University of New York at Stony Brook, an American Cyanamid dye consultant, said of Klingsberg's original contribution, studies on sulfur heterocycles containing two sulfurs in one ring, namely the 1,2-dithiolium system: "It is the type of thing I can hope to do once in my lifetime."[16] From dithiolium compounds, Klingsberg moved on to the investigation of nitrogen analogs, the pyrazolium nitrogen heterocycles.[17]

In accord with research practice, Klingsberg submitted his new compounds for general biological screening. One pyrazolium showed herbicidal properties and was to become the wild-oat herbicide Avenge. "Blue sky" is the term that Klingsberg and other chemists use when referring to random synthesis, often guided by hunches and intuition—though screening of chemicals for biological activity, developing and applying synthetic pathways, and subsequent improvements are anything but random.[18] Klingsberg's success in some ways broke new ground at Bound Brook. It was not imitative, nor an example of analog chemistry—except insofar as the research was originally stimulated by a new range of DuPont dyes—but based on "speculative" or exploratory research, that is, free-time research. In the industrial context, free-time research came close to basic research. There were several precedents, some stretching back almost a century.

The Research Tradition

The distinctive process of discovery in industrial organic chemistry was buried deep in the corporate culture. Many of its peculiarities stemmed from the 19th and early 20th centuries, and, notwithstanding sophisticated research laboratories, better technology, instruments, and modern theories, the mode of working was not much different in the 1950s, and even later. It is instructive here to briefly consider basic and "speculative" research at I.G. Farben's Ludwigshafen central research laboratory and elsewhere.

Around 1930, mainstream chemical problems abounded, and research planning seemed to be straightforward.[19] In 1927, the same year that Calco's Research Department was established, I.G. Farben and DuPont inaugurated basic research—while Phillips Petroleum Company opened a hydrocarbon research laboratory.[20] Chemists were encouraged to transfer from one area to another, and were competent to do so. Thus, when in 1926 the I.G. Farben Ludwigshafen director of research, Kurt H. Meyer, was confronted with the fact that 200 chemists were working on dye research, the expense of which could never be recouped from sales, even from novel products, he found a simple answer: "Today we see that I.G. employs too many organic chemists. We must take them out of the graveyards of the closed production [dye-screening, testing and research] facilities and confront them with problems in physical chemistry."[21] Ludwigshafen chemists, notably polymer specialists Meyer and Hermann Mark, "thought that basic research was a necessary complement of applied research," while catalyst experts Alwin Mittasch and Hans G. Grimm "saw basic research as a possibility for introducing the scientific spirit into their laboratory as a sort of scientific problem-solving."[22]

The emphasis on basic, or pure, research at DuPont in the 1930s was related closely to organic synthesis, polymerization, and catalysis. After American Cyanamid opened the Stamford laboratories in 1937, the corporation's research policy also encouraged greater diversity and a broader content than previously attached to the aromatic chemistry as practised at Bound Book.[23] This included research into polymers such as melamine.

In the United States during the 1950s and early 1960s, corporate research based on university practice became the dominant theme, with the construction of architecturally splendid R&D centers by such big firms as Dow, General Motors, IBM, and Bell Laboratories. In 1954, Allied Chemical & Dye Corporation inaugurated a new Central Research Laboratory at Morristown, New Jersey, and in 1957, the new Bound Brook research laboratories were opened. The general idea was to emulate wartime successes in turning basic science into useful products. However, these fabulous R&D facilities did not provide all the answers, and individual manufacturing divisions often contributed more to novel innovations than did the new centers.[24] Eventually these approaches gave way to a growing dependence on bureaucracy that favored security over risk, and the increasing insulation of organizational and management groups within the corporation from the realities of where manufacture and innovation stood. This trend probably started in the 1960s, when oligopoly—or at least competition between a few big well-established corporations—was no longer the driving force in innovation.[25]

That this was not untypical is evinced by Professor Herbert C.

Brown, who in 1974, after he dropped consultancy work for American Cyanamid, explained in *Chemical and Engineering News* that at "one time, both industrial and academic laboratories were active in doing exploratory work that could lead to new reactions and new compounds. They competed to some extent. More recently, we have seen industrial laboratories increasingly withdraw from such exploratory research. Their objectives are being much more narrowly defined, with very little effort being devoted to exploratory research ... The present policy of cutting out support for exploratory chemistry in order to emphasize quick solutions to current problems is shortsighted."[26] A few years later, Brown also bemoaned the fact that decision making in industry had been taken away from chemists and placed in the hands of accountants.[27]

More searching, and revealing, however, are internal American Cyanamid memoranda from the end of the 1970s. They reflect opinions and injunctions of researchers and managers of the moment. As components of a dialogue of internal disunity, into which were drawn research fellow Erwin Klingsberg, Intermediates R&D head William B. Hardy, and former Bound Brook laboratory director Guidi Mino, they are also sources for diagnosing the ills. One of the main objectives of both Klingsberg and Mino was reversal in the change of policy over free-time research, which the senior management at Wayne had scrapped in 1976. It was an issue brought to the forefront during the time when there was an urgent need for suggestions that might lead to a revival in innovation. The memoranda resonate with similar concerns elsewhere in the chemical industry, where all efforts to repeat past successes became elusive. Their value as rare firsthand historical documents from a period of uncertainty and self-questioning following decades of proven successes lies in the outspoken contemporary views of those with hands-on research and production experience. In the case of Erwin Klingsberg, his opinion drew on three decades as a Bound Brook research chemist, as research associate, and later research fellow engaged in free-time research.

Klingsberg's first boss, from 1946, was Hans Lecher, "a good research leader. He kept up to date with the literature." It was Lecher who encouraged Klingsberg's interest in the chemical literature. In Klingsberg's view, after Lecher retired in 1952, "research was controlled by generations of faceless bureaucrats. The rule was: 'Cover up, protect your rear, and don't ask questions—ask any Bound Brook employee.' Science management became unbelievably poor." Nevertheless, Klingsberg's qualities were greatly appreciated by Jay Leavitt, head of Exploratory Research during 1964–69.[28] Leavitt gave Klingsberg almost free reign through reallocation of the unused free-time research of other chemists.

Klingsberg's achievements and status as research fellow were such that, in accord with the program of sabbaticals, he chose to undertake research at the Cyanamid European Research Institute in Geneva during what was to be its final year. "Geneva was held out as its jewel, but it was a waste of money," Klingsberg says. "After operating for a decade without any apparent value to the company, it was closed at the end of the 1960s, and not mentioned in company histories." Within a year or two of the closing of Geneva there were cutbacks in research staff at both Stamford and Bound Brook, which did little to maintain confidence in the future among those remaining.[29] In 1969, Jay Leavitt was replaced as research manager by Michael M. Rauhut, who became Klingsberg's new boss.

Guido Mino, and Research at Bound Brook

In 1980, Guido Mino, then close to retirement, was commissioned by the senior management at Wayne to undertake an internal investigation based on staff interviews into how the performance of the Chemical Research Division (CRD), formed in 1972, might be improved. Mino was well-qualified for this assignment. He had behind him a long and distinguished career at American Cyanamid. Born in London, England, in 1920, he spent over two decades in Italy, where at the University of Turin he obtained a degree in chemistry and, in 1946, a doctorate for studies on metal corrosion. After teaching crystallography at Turin, he returned to England, where he joined ICI's Plastics Division at Welling Garden City, and undertook research into polymers. In 1949 he was at a commercial laboratory in New York, investigating improved plastics for dentures.

Two years later, in 1951, he was appointed a research chemist at American Cyanamid Stamford, where he undertook research into acrylonitrile and styrene polymers. Late in 1954, Mino was offered a post as group leader at Bound Brook. He moved to the facility in May 1955, where he first worked under research manager Jason M. Salsbury. Research topics included ceric ion-induced polymerization, and wrinkle-resistant resins for cotton. In 1960, Mino replaced Arnold Davis as research manager, Rubber Chemicals, and in 1972, he was appointed research director at Bound Brook, a post he held for two years before joining the International Division, also as research director.[30] In this capacity he was involved with the work of laboratories in England and Japan. In August 1977, he returned to Stamford as research director for the Industrial Chemicals Division, which included polyesters and certain other polymers. It was from there that on October 9, 1980, he completed his report on "Improved Utilization of Scientists in CRD" at the corporation's laboratories. Copies of Mino's report were sent to the "Office of the Director" at Wayne, and to five managers. His recommendations included greater R&D funding, reinstatement of free-time research, and improved career structures for research scientists.

Klingsberg would later publicly drew attention to the implications of the Mino report in his account of a case of age-related unfair dismissal against American Cyanamid (settled out of court in 1984). Klingsberg observed that the

> environment deteriorated dreadfully in the late 1960s. What happened, in a word, was that research was taken over by bookkeepers ... The result was total demoralization. When it became clear that nobody in the Chemical Research Division was prepared to take corrective action or even to admit that a problem existed, I myself went to the chairman of the board of the company [James G. Affleck], and put the case to him. He freely admitted that things were in pretty bad shape and promised to do something about it, but never did. By that time the top management was beginning to wake up to the fact that the money being spent on research didn't seem to produce much result, and they commissioned a retiring research director [Guido Mino], who like me had spent many years with the company, to draw up a diagnosis of the ills of Cyanamid research. He produced a blistering indictment of the way research was managed—or rather mismanaged in the company. His perspective was of course different from mine. He was a research director and I was a bench chemist, but we both came to similar conclusions: (1) Research at Cyanamid was a shambles; (2) It was very doubtful whether anything could be done about it.[31]

Klingsberg recorded that "early in 1981, my boss [Rauhut] recommended me, in recognition of outstanding accomplishments, to be appointed Distinguished Research Fellow, at the top of the professional ladder." This at least was some compensation for the demotion he had suffered five years earlier when free-time research was scrapped. In the late summer of 1981, however, after attending a heterocyle conference in Graz, Austria, where Klingsberg spoke on novel vat dyes, he was fired.[32] In 1994, Klingsberg was elected to the New Jersey Inventors' Hall of Fame in honor of his achievements at Cyanamid.[33]

The mood during the 1970s was certainly in sharp contrast to the optimistic picture presented by management in the 1950s and 1960s. In the 1950s, American Cyanamid inaugurated a number of initiatives aimed at encouraging creativity and self-improvement among research staff, including junior educational awards, advanced educational opportunities, consultations with academics, and free-time research. Laboratories were enlarged, and the latest instrumentation was installed, in keeping with American Cyanamid's early adoption, and improvement, of instrumental techniques. The official picture was that free communication was fostered between laboratories, and stimulated by staff exchanges among Bound Brook, Stamford, Lederle, and, later, the Agricultural Division's laboratories at Princeton. This was extended through the annual conferences held each October at Skytop (later held at the Italian Center, Stamford). Investors and staff were advised that the Research Coordinating Committee, made up of all research directors, ensured that research results were shared among the different laboratories and divisions, sometimes with unexpected but highly promising outcomes. Thus investors' imaginations were captured by the facts that discoveries in the textile research laboratories contributed to a Breck hair conditioner, and rubber research aided the development of a Lederle anti-tuberculosis drug.

In reality, at least as far as Bound Brook was concerned, the picture was less clear. In 1958, Dr. Richard K. Madison was transferred from Stamford, where he had worked on radioisotopes as tracers, to the Bound Brook research laboratories. Madison was disappointed by the lack of contact between the various Bound Brook and other laboratories, and total lack of confidence from senior management in the results of research. The scientific work, carried out by "good people who did good research," was "fragmented, split up, and with little cross fertilization." Meantime, during the 1960s, research managers, with what appeared to be considerable optimism, described the latest research before the Management and Finance, or M&F, Committee, comprised of corporate executives from the General Staff, and divisional presidents, vice presidents, and directors of research. The main outcome was pressure for useful innovations. One research manager, frustrated at lack of results, made his chemists personally "responsible for running one or two meaningful experiments every day." In general, as far as Madison was concerned, despite "laboratory work, reports, and recommendations, nothing was done, that was the end of it."

In the early 1970s, Madison was a group leader in Exploratory Research at Bound Brook, managed by Rauhut. His colleagues there included research fellow Erwin Klingsberg. Madison's responsibilities focused on "laying out fields for ten years ahead." Among his proposals was that Lederle engage in gene therapy. At first, Lederle expressed little interest, but eventually, after Madison's continued plugging this line of inquiry, persuaded a chemist from Stamford to travel to Bound Brook to meet with Madison. The chemist reported that the future was too far away, and the proposal was hardly worth looking into.[34] According to Madison, American Cyanamid preferred to buy in new technology, rather than believe in its own people. Certainly, as had long been the tradition, American Cyanamid engaged extensively in licensing processes from outside inventors and overseas firms. (Nevertheless, as Jay Leavitt points out, newly acquired processes were often improved considerably at Bound Brook, and there were some entirely novel inventions that were successfully commercialized.)

One day, Robert Long, following a visit to Germany, came to Madison with an "amazing" story, one that was also telling of management attitudes at American Cyanamid, as well as at other American corporations. The German firms, according to Long, were run by Ph.D. scientists who were also businessmen! This reflected the great reliance on the prevailing business school philosophy in the United States, which meant that senior executives increasingly came from those with marketing, legal, or financial backgrounds. Hardy, Klingsberg, Leavitt, and Von also agree, as discussed in the previous chapter, that for some Organic Chemicals Division (OCD) presidents the attitude was: "a manager was a manager and the business area didn't matter."[35] Perhaps a greater difficulty was that of coming to terms with the fact that while before 1960 it was, as Forlenza emphasizes, "impossible to make an error in the chemical industry," this was no longer true in the 1970s, irrespective of who presided over divisions or belonged to executive committees.

The End of Free-Time Research

In endorsing "free-research-time" at American Cyanamid in 1954, "research management felt that programming should be sufficiently flexible that every professional chemist should have an opportunity to do some unrestricted research, time to be provided by leaving unprogrammed some 10% of the research effort."[36] There were, however, certain inherent problems, as even the strongest defender of free-time research, Erwin Klingsberg, pointed out in 1969:

> Many chemical companies attempt to foster creativity among their scientists by encouraging them to work on their own ideas, without any accountability, during a certain proportion of their time. It seems that in most cases the allotment of time goes unused. Why? In all probability, because of fear. Fear of making a mistake. Fear of looking ridiculous. Fear of annoying the supervisor by taking time away, or seeming to take time away, from the principal object, the assigned project. All these fears prevent us from making the best and freest use of our talents.[37]

Notwithstanding these limitations, Klingsberg was the major beneficiary and proponent of free-time research, receiving, through Leavitt, the unused free-time research allocations of other Bound Brook chemists. Klingsberg was enabled to undertake full-time "uncommited exploratory research," through which he discovered the heterocyclic compound that was transformed into Avenge.

Jason Salsbury was appointed head of the new Chemical Research Division (CRD) in 1972.[38] He and others in the corporation confronted problems of poor innovation, and lack of motivation following staff cutbacks in 1971. On October 25, 1972, the direction of research at American Cyanamid, particularly the need to take risks and move in new directions, was discussed by the corporation's president and chairman James G. Affleck in his address to the Cyanamid Fall Technical Conference. Affleck made an urgent call for completely novel strategies. It was at the same time an admission that for a number of years results had not been forthcoming. "Successful research which allows us to bring to market distinctive and patented new products is the only way we have to absolutely assure a competitive advantage ... We need to concentrate on new approaches to solve important problems. ... Our research activity must be more pioneering in character and that requires bravery, a high level of aspiration and an overriding sense of urgency."[39]

Similar difficulties were occurring elsewhere in the chemical industry, and not just in research departments, as a "new generation of leaders was called upon to carry out the socially painful and politically delicate job of rationalizing and restructuring the chemical industry through layoffs and plant closures ... and of determining in a case-by-case basis the sectors that should be abandoned."[40] Lax management, overstaffing, extravagent sudsidies for R&D, and expensive or unwise acquisitions had all contributed to this situation. Then from 1973, high energy costs became an additional burden. Often, in response to market forces, projects were hastily assembled, with little time for proper planning.

According to Klingsberg, one of Salsbury's responses was to eliminate free-time research.[41] Undoubtedly, this was not Salsbury's decision alone, though he may have suggested it, or agreed with the proposal. Final approval would have required a "nod from higher up."

Irrespective of how it came to be implemented, this action meant, according to Leavitt, "abolishment of the dual ladder, managerial and scientific, of which [Klingsberg] had had the major advantage."[42] Klingsberg was now demoted from senior research fellow to bench chemist, without special privileges. This prompted the highly aggrieved Klingsberg to raise the issue of research needs with Affleck in November 1976.

1. In a series of meetings held in the late 1950s, our research staff was asked by the management to attempt to discover new chemistry, without regard to

specific applications. The creation of AVENGE (and other promising compounds) was a direct result, and shows how Cyanamid can profit from "basic" or "long term" research properly conducted in the company interest.

2. Cyanamid's prestige in the international scientific community was enhanced by the pioneering heterocyclic research that produced AVENGE, making it easier to attract highly qualified chemists, particularly at times when they may be scarce. Scientific leads produced by this work are being pursued by investigators at Monsanto, DuPont, IBM, and other industrial and academic research laboratories.

3. Our research atmosphere, relatively permissive during the 1960s, has become too restrictive and needs to be liberalized by reinstatement of the free-time rule and other steps.

4. Outstanding research accomplishments are not rewarded financially, with the result that capable and creative experimentalists who want to "get ahead" leave the laboratory, while chemists who stay at the bench have little pecuniary reason to work hard.[43]

Subsequently, Klingsberg raised his concerns directly with Salsbury. In March 1978 he wrote:

As you pointed out in a very generous letter that you sent me some time ago, AVENGE^{R} originated in a program of "basic" or "long-term" (i.e. not goal-oriented) research initiated by management in the late 1950s. The creation of AVENGE and other promising products shows the way in which sound strategy in such research maximizes the chances of success in the marketplace. From discussions that we have had, I think we agree that this crucial question of research strategy, with its bearing on research possibilities, was often overlooked in Cyanamid laboratories during the '50s and '60s, contributing to repeated failures and finally to the abandonment of long-term research. Now it is hard to believe that a company as large and as diversified as this one can find no place at all for such research, and I propose a new plan, revival of the free time rule on a selective rotating basis, to be administered something like our advanced study grants. This would avoid the past difficulty with free time, that the available 10% was little used, and it would afford a number of important benefits: (1) To our younger chemists, the opportunity to demonstrate exceptional creative talent, and to management, assistance in discharging its vital responsibility for the discovery and encouragement of research talent. (2) At little cost to the company, the plan would provide a powerful stimulus for new explorations. (3) It could help meet the long-standing need of the CL [Chemotherapy Laboratory] file for new substances, and Cyanamid's need for another AVENGE^{R}. (4) Out of all proportion to the minor fraction of the total research budget that it constituted, it would give a much-needed lift to morale, motivation, and productivity throughout our laboratories, thus increasing our prospects of meeting the stated goal of $50 million new product sales.

A little over a year ago I put forward some of these ideas in a conversation with Dr. Affleck, and I believe that this plan represents a blueprint for successful action.[44]

Salsbury's response was to request a plan of action, which arrived from Klingsberg four weeks later. Klingsberg's proposal was quite modest, namely to start by providing free-time research for two chemists.

In response to your request, I am happy to supplement my memorandum of Mar. 29. The plan would work out as follows:

(1) Chemists are invited to submit proposals for research projects thought to be in the company interest, but outside the sphere of the budgeted research effort.

(2) A management-appointed review board evaluates each proposal and selects the most promising. Such a board should include able and creative experimentalists, who would be well qualified to judge the merits of the proposals and their authors.

(3) The chemists selected are authorized by management to perform the approved research full time for a fixed term (say one or two years), approval including what is thought necessary in the way of special equipment, technical assistance, etc. The progress of the work could be monitored by the same review board.

(4) When the time is up, the review board examines what has been accomplished in terms of the original proposal, impact on other company programs, new leads, CL file submissions, etc. Appropriate recommendations are made.

As well as I can estimate, there are perhaps 200 chemists in the CRD who would be eligible. Initially, participation could be limited to the 1% level (i.e. 2 chemists), with the possibility of expansion contingent on the quality of the proposals and results.

Whatever the scale of the program, it stands to benefit by a strong element of self-selection: The participants will have shown that they have ideas and the ambition to work on them, and they will be powerfully motivated to succeed in their own proposals. Their later work is likely to profit by the experience of free-time research, and we can imagine a growing cadre of chemists, who, by their participation, have acquired a new degree of motivation and a new habit of thinking in terms of the broad company interest.

I could comment at much greater length but will simply reemphasize my conviction, based on 32 years' experience in our laboratories, that such a program, far out of proportion to its very limited cost, holds the promise of great benefit for CRD and for American Cyanamid.[45]

Internal Dissent: Internal Correspondence

The organizational problems, lack of rewards for research, shortage of researchers, and loss of expertise also worried Guido Mino, who, soon after joining Stamford in 1977, made certain of his concerns known to Salsbury. In 1978, Mino reinstated free-time research at Stamford, where a new Discovery Research Department was created. In July, he again raised his concerns with Salsbury, in a memorandum headed "Improvement of Creativity in R&D." He was highly critical of R&D management and, in particular, of the absence of financial rewards for research scientists.

Eleven months ago, when I joined the Stamford Laboratory, I expressed concern with the apparent lack of creativity and innovation in many of the R&D groups. You showed the same concern and asked me to do something about it. Eleven months later, I cannot claim to have improved the situation, but I have singled out some of the causes which, in my opinion, stand in the way of innovation in my department and I am writing them down for the purpose of discussion.

In my view, to get innovation one needs the right kind of people and the right kind of environment. We can more readily change the environment than change the people, although something can be done in this direction too. The environment must provide the desire to innovate and the time and means to innovate. One thing that struck me when I joined Stamford is that the managers set schedules so tightly that the scientists do not have the time to try out new ideas or even to keep up with the literature, except in a narrow field. If this is allowed to continue the scientists will lose the drive to inquire and the knowledge required to innovate; they will become technically obsolete. Our environment is not conducive to innovation, it is not even apt to keep innovative people in positions where they can innovate technically. In our performance ratings we tend to reward well organized, productive people that achieve short-term objectives. Creativity is not demanded and not rewarded by the Company and not stressed by Middle Management. Creativity should play a greater role in the performance rating of R&D personnel. We tend to reward well people that can manage and penalize creative people that cannot or are not inclined to manage. We are annoyed with some creative people because they do not "fit" and are hard to manage and wish them away.

One of the reasons why many creative people are lost to research in our Company is that our system only rewards managers. The creative scientist in order to grow within the Company must learn to manage, even if he is not inclined to manage. This often has the doubly deleterious effect of converting top technical people into poor managers. If the scientist does not grow in management, he has no room to grow at all; he has no status within the Company and as he grows older he is looked down [upon] as somebody who did not quite make it. He is not a success. There is little wonder that older scientists in industry become discouraged, sparkless and often technically inadequate. I am now making generalized comments which extend to industrial R&D rather than R&D in my department. This is in a way dangerous because the further one moves from his direct experience the less valid his opinions become.

Mino made a direct connection between the dismal lack of successful innovative activity and the low status accorded to those at the bench: "I cannot help wonder, however, whether the plight of industrial R&D in this country is not related to a large extent to the lack of opportunity and the low degree of esteem reserved for the industrial scientist." Where good research was conducted it was invariably by those from foreign climes: "The fact that American youth is now shunning industrial research must be symptomatic of something. Our research labs are more and more staffed with young men that came from other countries. I have nothing against them, being one of them, and even grant that they may be as competent as the natives, but the natives are shunning industrial R&D for something better."

Returning to the immediate problem of improving the environment in American Cyanamid laboratories, Mino planned to implement the following steps: "1. Stress the importance of creativity and innovation in performance reviews. 2. Make innovation part of the managers' objectives; Relax schedules and bring longer-term projects in the programs; Reward creativity within the framework of our salary administration." Mino emphasized that management

should stress the importance of creativity in R&D and should be prepared to reward it. Something must be done to improve the status of the scientist within the Company. One can have a scientific ladder, [with] monetary rewards for inventions and patents. I realize that we had a scientific ladder which we finally abolished because it did not work. It did not work because it became a receptacle of mediocre people who did not succeed in management. It was not the fault of the ladder, but of the R&D management which abused it. I am not advocating that we go back to the old system, which was in many ways impractical, but that we consider increasing the status of scientists with titles and monetary rewards. Rewards for inventions are difficult to manage, they tend to create bones of contention among scientists and require managers with the wisdom of Solomon. These arguments have often been brought up by R&D management and they are valid, but they are no excuse for doing nothing.

He then turned to demotivation and, in particular, the problem created by the relatively low salaries offered by American Cyanamid:

People are the most important ingredient in innovation. There are groups at Stamford where there is an abundance of outstanding people capable of innovative research. I am referring to many of the people in Sponsored Research. Upon looking at my people, I have the impression that some of the ones that have been rated outstanding performers are less than that and also they are not creative. If these people were capable of outstanding performance when we hired them and now they are not, we must have demotivated them by our practices and by our environment.

It can also be that we do not attract outstanding people because our starting salaries are too low. In my department this year we have been singularly unsuccessful in hiring any of the top candidates interviewed. It is our opinion that the salaries offered were too low.

The fact that most of our people rated outstanding are not creative is indicative of the criteria used in our performance rating system which I already discussed.

It only takes a glance at published salaries paid to chemists in industry to figure out that Cyanamid's salaries are below those paid by the major chemical industries by 10–20%. This has been true ever since I can remember. The fact that Cyanamid has been able to keep able people in spite of this speaks well for the Company and perhaps poorly of the initiative of the employee, or perhaps it means simply that when people have settled and begin to accumulate benefits in one Company they are not likely to move for an increase in salary of 10–20%, especially in the face of pension benefits that are lost in transit. I cannot evaluate the effect of lower salaries on motivation and innovation of scientists, but it can only be negative. Anyway the compression in salaries makes it difficult to offer competitive starting salaries. I believe that top management should take the following steps:

1. Stress its expectation of innovation by issuing directives to Division Presidents and Directors.

2. Require that Division Presidents have long term objectives which require innovative R&D (rather than short-term objectives to take care of the business of today).

3. Study and adopt a system to improve the status of scientists.

4. Change our salary administration policy to make our salaries competitive.[46]

Less than two weeks later, Klingsberg was advised that his proposal for reinstatement of free-time research had been turned down. "What followed was like Kafka but without Kafka's humor. My ideas were turned down by Salsbury's staff in a series of meetings to which I was not invited. At least that's what he told me in a telephone call … Salsbury doubtless figured that … I would stop annoying him. Instead I called up friends working for other companies, and used what they told me to show … that free-time research had created enormous profits for firms like Merck, Exxon and Upjohn." Klingsberg was livid, and, on August 3, responded to Salsbury, in the most diplomatic way he found possible,

I appreciate your calling to inform me that your staff had held a series of meetings to discuss my plan for reinstating "free-time" research as outlined in my memos of March 29 and April 27 and had decided not to take action at present.

Convinced as I am of the importance and indeed urgency of this matter, I should like to bring to your attention the following success stories from other companies. I regret not having attended at least one of your meetings where I could have presented these case histories in more detail.

1. INDOMETHACIN, antiarthritis drug with current annual sales of $160 million. Created by free-time research at Merck.

2. ECA-7500 LUBE OIL DISPERSANT, current annual sales $6–7 million. Created by free-time research at Exxon.

3. PROGESTERONE, microbial conversion to 11-alpha-hydroxyprogesterone. Key process step in manufacture of steroid products with annual sales over $100 million, discovered by free-time research at Upjohn.

4. LIGAND DEVELOPER 2-(2,5-dihydroxyhydrocinnamoyl)cyclopentanone, key intermediate in the manufacture of instant color film with annual sales well over $500 million. Created by free-time research at Polaroid.

5. ALDOMET, hypotensive drug with current annual sales of $300 million. Crucial racemization step discovered by free-time research at Merck.

6. ION EXCHANGE RESINS, including DUOLITE A7, with total sales to date of $100 million. Created by free-time research at Diamond Shamrock.

In the laboratories responsible for these achievements, the free-time rule remains in effect as settled policy. The list could easily be extended, but I think it is long enough to show that the discovery of AVENGE^{R} was a typical demonstration of the immense value of free-time research when properly conducted with a view to the company interest.

I sincerely hope that you will see fit to reconsider the question in the light of this evidence.[47]

Klingsberg explains that Salsbury's response to this letter "was to call me up and threaten to fire me." He turned for advice to a friend, "a physical chemist who had worked at Cyanamid for many years and at this point was quitting in disgust in order to attend law school ... I followed his advice, which was to send handwritten apologies ... to both Affleck and Salsbury; I think the latter then graciously withdrew his threat at a luncheon we had together."[48]

It was also in August 1978 that Salsbury and Dr. A. T. Guertin reviewed responses to a detailed questionnaire on "obstacles to innovation," circulated among members of an American Cyanamid team enrolled in a course on management innovation provided by the consultancy firm SRI (known as Stanford Research Institute until 1977). The principal conclusions described the needs for: removal of barriers to innovation, and provision of incentives; letting employees know that management wanted innovation; establishing a monitoring system; and planning for the future, "so research can follow a long term plan—have contingency plan." Salsbury observed: "I was most impressed by the actions many of you plan to take to encourage innovation by your people ... Perhaps they will suggest ways each of us can improve our management techniques."[49] Later in the same year, American Cyanamid completed a program of research reorganization that created five separate research divisions: agricultural, medical, specialty chemicals, consumer products, and Formica brand products. However, questions surrounding long-term objectives remained, as did the problem of the future for Bound Brook research.

In August 1980, Mino advised Hardy that in his opinion the Bound Brook facility had a poor record of research successes. While disagreeing on this point, Hardy did concede to Mino that a major demotivating factor had been the staff reductions in 1971. Moreover, Hardy was highly critical of the commercial departments that held no truck with long-term research.

This is to summarize some thoughts on possible ways to increase R&D productivity particularly with reference to the Bound Brook laboratory. At the onset I wish to emphasize that while it is certainly desirable to try to improve productivity, I am not in agreement with the idea that the Bound Brook Laboratory has not been productive over the years. Indeed we all know that many profitable products have been discovered and developed at this location.

I must admit, however, that there appears to have been a drop off in productivity at least in some areas in the past several years. Viewed in historical perspective it is my belief that great damage was done to the organization in 1971 when extensive cuts were made in the staff. While some of the people released were marginal producers, the overall effect was to create a certain amount of cynicism and suspicion of management that eventually culminated in the effort to unionize in 1974. Although unsuccessful, this organizational attempt was supported by a substantial number of laboratory personnel, a situation that I believe would have been unthinkable before 1971.

What appeared to be a gradually improving situation suffered a setback with the realization on the part of the chemists that entire areas of research (dyes, for example) were being eliminated. This in itself was understandable, but the feeling existed that new areas of research should have been initiated to replace those that were eliminated. In the past year with the realization that many OCD businesses are in trouble the feeling has developed that the laboratory and the jobs it offers will be eliminated.

It is within this framework that I would now like to point out some more immediate and specific reasons for morale being lower than desired at this time.

1. What is perceived to be a very weak and overly cautious effort to commercialize products that appear to offer real promise. The industrial chemist who is truly interested in his profession derives satisfaction on his job only if he feels an honest effort is made to utilize the results of his work.

2. Undue interference with day-to-day research activities by the commercial department.

3. Extreme pressure to meet objectives in unreasonably short time periods. It is recognized by the chemists that the need for meeting the objective is real. However, they feel that the urgency resulted from poor commercial intelligence in the first place and they are now paying for someone else's mistakes.

4. There is a tendency to stop projects on a whim. "If a product has been found then we do not need to do further work in the area." "If a product is not found in 3 months then that project should be stopped." This approach makes it virtually impossible to achieve results having real value and is extremely wasteful. A specific example is flame retardants where we were told not to do further work until market studies were compiled. One year later the market study is still not done and the project remains in a poorly defined state.

5. A highly disturbing problem which troubles every chemist in the laboratory is the difficulty of initiating work in a new area. Company management beginning with commercial department management gives lip service to the need for entering new areas. In the past few years many possible new areas for research have been proposed, but little has been done. Even such obvious extensions of our own product lines as nontoxic heat stabilizers for PVC do not receive support.

Photoinitiators can be cited as another example. Here the area is closely related to the technology of light stabilizers. Proposals to enter the field were made in 1973 when the area was relatively new and a small effort was initiated at the insistence of R&D personnel. However, in the intervening 7 years we have had 5 different commercial department managers and the work has been started and stopped about as many times. It is estimated that if research in an area is stopped for 2 years productivity is interrupted not for 2 years but for 5 years ... In the meantime CIBA-Geigy has maintained a strong R&D effort and, in addition, has acquired products from Union Carbide which are selling at the rate of several million dollars a year. As in other areas, I believe CIBA-Geigy success must be attributed to management commitment and foresight, not to their having a superior R&D organization.

Hardy also expressed great concern over a recent decision to transfer all remaining Bound Brook exploratory, or discovery, research to Stamford.

6. There is considerable feeling that CRD management has not decided what to do with the Bound Brook laboratory. The recent organizational changes at Stamford indicate that all discovery work will be done there. On the other hand many OCD business areas are declining in profitability to the extent that they cannot or will not support research. Up to this point no one has talked to Bound Brook personnel concerning the future of the laboratory although this has been done at Stamford.

Problems of morale are inextricably related to productivity and I believe that if the reasons for low morale pointed out above were removed, productivity would rise.

Specific steps that could be taken to improve productivity are:

1. Explain CRD's position (if one exists) with respect to the future of the Bound Brook laboratory to all personnel.

2. Initiate new R&D projects at Bound Brook. It is well established that the longer a group works in an area the lower its productivity becomes.

3. CRD top management should make an effort to meet informally with Bound Brook personnel.

4. Eliminate day-to-day interference with R&D programs by the Commercial Department.

5. Maintain continuity in programs. Once a project is approved, chemists should be allowed to work at least until the time set by the objectives.

6. Consideration should be given to conducting more complete "in house" sessions with the chemists on the subject of product research and development. This would be primarily useful in the indoctrination of the newer chemist in the background, techniques, requirements and broad approaches to a project. He would learn in a short time what might otherwise take a year or two. Perhaps an outside speaker could be useful to point out new approaches.

7. Teach Bound Brook personnel the use of computer terminals on a "time share" basis, similar to that used at Stamford for synthesis work. This would improve technical competence.

On a somewhat different plane it would be helpful to improve analytical services. A particular problem that continues to plague the synthetic chemist is the long time (3–4 weeks) required to obtain microanalyses. Complaints such as the air conditioning (or lack of it) are not basic sources of dissatisfaction. Salaries, meeting attendance and other benefits may occasionally give rise to problems, but again are not basic causes of poor morale at this time. I believe that the workshops initiated by the Synthesis Subcommittee a few years ago have been of considerable value for information exchange and morale. Recently Dr. R. W. Thomas has proposed luncheon discussions in which Synthesis problems will be reviewed. These should be useful in increasing productivity of the synthesis chemists in the laboratory.[50]

The Mino Report

And so it was that Guido Mino was commissioned to undertake the investigation into how the performance of the CRD might be improved. After completing a number of interviews, he presented his proposal for revitalizing research throughout the company in the fifteen-page position paper, "Improved Utilization of Scientists in CRD." There was clear acknowledgment of the important and formal role that marketing departments now played in determining R&D strategies.

The original objective of this investigation was to study and suggest ways to improve the utilization of top scientists in CRD. By better utilization of scientific talent I mean increased creativity and innovation, increased motivation and productivity. The final goal is to have total involvement of our top scientists in the preparation of long-term research programs that will shape the future of the Company. As the investigation progressed, however, it became clear that the utilization of scientific talent is only part of the problem facing CRD and that the main objective ought to be the improvement of research productivity. From a pragmatic point of view, research productivity is measured by the success or failure of new products in the marketplace and of new processes in the plant.

Thus, research productivity is the final result of effort in research, manufacturing and marketing and can only be improved by a concerted effort in all these areas.

As to the problems of the scientific community in CRD, it is apparent that they are deep-rooted and complex and that a cure will be slow and difficult and will require definite commitments not only by CRD management, but by corporate management as well. These problems transcend the research organization and are deeply involved with the commercial departments and what is felt is the attitude of management towards research. There is a credibility gap between management and scientists which built up during the years, and cannot be overcome by simple words and promises. As I interviewed many people and discussed with them the positive steps that were needed to improve the situation, I noticed a willingness to discuss the problem, and to contribute suggestions on how to solve it, but also a great deal of skepticism that anything worthwhile would be done. In the words of one of the people interviewed, "research in CRD has fallen off the cliff" and it will take a great deal of effort and good will to bring it back. I am convinced that this can be done provided that top management is willing to put in the time and the effort not only in a burst of initial enthusiasm, but as a continuing policy aimed at protecting and motivating its human resources ... this report will outline several suggestions on how to establish and implement such a policy.

Mino then summarized the detailed suggestions contained in the main body of his report. He made a number of recommendations, including: collaboration between CRD, corporate management, and what he called the "Chemical Divisions" (which included OCD and Industrial Chemicals); a basis for funding research from what had become the dominant corporate functions, the various profit centers; loosening of time lines on projects that may not pay off for several years; the establishment of an improved career structure for creative scientists; and participation of scientists in long-range planning that was independent of constraints imposed by the profit centers. The emphasis was not only on the failings of research and corporate management, but on divisional management as well.

The decrease in research productivity during the years is a symptom of a general malaise within the Company which is caused, in my opinion, by a philosophy of management which stresses short-term profits at the department level while advocating long-term objectives at the corporate level. R&D has been caught in the middle and has failed to satisfy the expectations of either the departments or the corporation. The increase in research productivity cannot be accomplished by CRD management alone; it requires the involvement of corporate management and of the management of the Chemical Divisions at all levels. CRD can provide a better environment that motivates scientists and increases creativity and innovation and can recruit outstanding people but it cannot by itself improve research productivity within the existing organizational constraints.

Top management must resolve the dichotomy between its long-term wants and the short-term needs of the profit centers. Research must be shielded from conflicting demands on its resources and given guidance on how to establish long-term objectives. These cannot be born in a vacuum, but must be the result of long-range planning in CRD, the Chemical Divisions and the Departments and be supported by extensive and competent market research. Since most long-term projects will originate in research, it is important that CRD develop a function for evaluation of new technologies and for market research. Within the present system, the profit centers have no incentive in sponsoring long-term research and to spend money and effort to introduce new products in the marketplace. They are concerned with present earnings and shun any activity that has a negative impact on them. Research sponsorship is limited to short-range projects that have immediate impact on earnings. It is suggested the present system of funding R&D be changed to one where the profit centers must contribute a fixed percentage of their sales to the R&D budget, irrespective of the amount of R&D that will benefit their business. The percentage of sales is to be fixed by the Corporation, based on previous experience and present goals, and the profit centers will have to compete for R&D funds which will be allocated on the basis of potential earnings. It is also suggested that R&D be given responsibility for new products introduction and for interim production in selected areas, such as fire retardants for plastics, on an experimental basis.

With regard to creativity and innovation the number of creative scientists remaining in CRD is rather small and every effort should be made to motivate them to become more productive. This must be a continuing goal which cannot be accomplished overnight.

As a first step these scientists must be identified and given some form of visible recognition. It is suggested that a scientific ladder be re-instituted to provide recognition, rewards and an opportunity for growth for our top scientists. While management should have the right to nominate candidates, the appointments must be made by a Committee of Cyanamid's Consultants and of people already on the ladder (peers). These scientists will be working on self-generated long-range programs approved by the management. Their work should be monitored by the Director of Discovery Research [at Stamford]. These scientists should be provided with technical help to increase their output.

The environment for R&D must be improved drastically. The environment must offer freedom of inquiry, worthwhile objectives, recognition and reward for outstanding work and a continuity of programs which is now almost totally lacking. An essential step in providing a better environment and spurring creativity is the reinstatement of free time and the creation of a forum where scientists can communicate and be catalyzed by the ideas of others. It is proposed that Working Seminars be reinstated where scientists are expected to participate and be the speakers on a rotational basis. The seminars should be initiated by the Discovery Research Department.

For the future, there must be a long-term objective and an intensive effort to hire truly outstanding people and the Discovery Research Department should act as the recruiting arm for CRD in this endeavor.

Participation of top scientists in the preparation of long-term programs must be not only encouraged but demanded. A formal mechanism must be established to evaluate and select the proposal via a Review Board which includes management and the consultants. The Board should be chaired by the Director of CRD. The author of the proposal should be allowed to present his ideas to the Board and be informed of the Board's decision. The Board should review the projects on a fixed schedule and decide whether they should be continued, expanded or terminated.

All the changes advocated to create a better environment in research and to improve productivity will only work if corporate management is committed to sponsor long-term programs in our laboratories and to unshackle R&D from the short-term objectives of the innumerable profit-centers that make up the Chemical Divisions. Short-term work for the departments should be done in R&D to keep the businesses competitive, but the amount of short-term research should be clearly defined and programmed and should not interfere with the long-range programs.

Recommendations

1. Institute a new system of sponsoring R&D whereby the profit centers

are assessed by the corporation X% of their yearly sales and must compete for R&D funds which are allocated on the basis of potential earnings.

2. Give R&D the responsibility for new products introduction in selected areas on an experimental basis.

3. Reinstitute a scientific ladder to provide recognition and opportunity for growth for our top scientists.

4. Make the appointment of scientists to this ladder the responsibility of a Committee made up of Cyanamid's consultants and of peers; management can nominate candidates, but cannot appoint them.

5. Reinstate the use of free-time research as a means of spurring innovation and creativity.

6. Reinstate working seminars as a forum where scientists can communicate and can be catalyzed by the ideas of others.

7. Establish a formal mechanism for the evaluation and selection of long-term research proposals via a Review Board which includes management and Cyanamid's consultants.

8. Institute a dedicated market research function within CRD to evaluate the potential of long-range programs dealing with new technologies.

Mino also commented on the career choices then open to outstanding researchers. Invariably, status and higher pay were to be had only by entry onto the management track. This removed creative research leaders from laboratories, and was sometimes a default choice, as was well-recognized, since good scientists did not automatically become good managers. There was almost a complete absence of incentives for those remaining at the bench, even when their discoveries became successful products. Mino observed: "Our present system does not demand nor does it reward creativity," the shortcomings of which had been presented to Salsbury in the memorandum "Improvement of Creativity in R&D."[51] However, rather than dwell on these issues, Mino now outlined "some positive steps to improve creativity" that included a means for identifying and appointing creative scientists, improvement of status for scientists, reinstatement of free-time research along the lines suggested by Klingsberg, and improvement of the working environment. This involved three steps.

The first one must be the recognition of our top scientists in some visible manner. If these people are special to us, we must let them and others know that they are important. Most of us have seen the recent full page advertisement by IBM in the New York Times ... showing what the company thinks of their creative people. I suggest that Cyanamid institute a scientific ladder that allows our top scientists recognition and an opportunity to grow and to be rewarded. Once the ladder is established, management must limit its activity to nomination of new candidates and must have no say in the appointment of new candidates. These should be appointed by a Committee made up of people already on the ladder (peers) and by our consultants. By not giving management power to appoint candidates, it is hoped, we will avoid making the scientific ladder a dumping ground for unsuccessful managers and supervisors. This was the main cause of failure in the past. The levels on this ladder should be at least two, the present principal scientist being the first. Once the ladder is established, one can use several approaches to make use of this scientific talent. Most commonly, these scientists would be working on self-generated long-range programs approved by management. Their activities should be closely related to those of the Discovery Research Department at Stamford and should be monitored by the Director who, presumably, will have as his main goal the implementation of long-term research as a means of providing new opportunities for the Company. These scientists should be provided with technical help (one technician) to increase their output and avoid wasting their time on simple tasks that can be done by less trained and less gifted people. Although they would be expected to work at the bench, they would have more time to keep up with the literature, write papers, attend seminars and meetings, and keep in touch with other people working in related areas in universities and, whenever possible, in other industrial laboratories. It is important that these scientists be given some sign of visible recognition such as a small office, in the laboratory, that sets them apart and gives them a certain amount of status and prestige.

The second step in improving creativity must be the reinstatement of free time in CRD ["Free Time Research," E. Klingsberg to J. M. Salsbury, April 27, 1978, and August 3, 1978], not just by telling the people that we want them to do it, but by creating some kind of inducement and expectation. In 1978 I reinstated free time in my Department at Stamford. I first tried to convince the managers and supervisors of the necessity of the free time to generate and try new ideas. Then I spoke at length and forcefully to each group, while I was reviewing each project, and explained to the chemists that I expected a change with more relaxed schedules and the use of free time. Even when new managers were brought in, who believed in free time, there was little improvement. Only a few people went out of their way to do exploratory experiments, the others continued to work full time on their assigned projects. Maybe the environment was not right, maybe the concept of free time was not stressed enough, but I suspect that even in a better environment, only a few people will take advantage of free time. Regardless, it is important that we create the right environment for exploring new ideas, that we encourage the people that want to use free time, that we reward creative people with high ratings and compensation. I believe that in the proper environment the creative people act as catalysts and stimulate others to explore and become more creative. The catalytic effect of the creative mind on other people in the laboratory cannot be overemphasized. We have all seen islands of creative work flourish in many parts of the world. Notable examples are the Fermi group in the late thirties in Rome and the Natta group in Milan in the fifties. I single these out because they were true islands flourishing in a country where scientific research is not generally encouraged nor well funded. Yet, the creative leader attracted outstanding scientists, provided the right environment and achieved outstanding results.

Mino's third step was the improvement of the working environment as a means of stimulating creativity. It had to be conducive to innovation and not a barrier to it. This included a forum in which scientists could communicate and exchange ideas on a regular basis.

During my discussions, many people suggested the reinstatement of working seminars where scientists are expected to act as speakers on a rotational basis and participate in the discussion that ensues. The new Discovery [Research] Department should act as the hub and take the initiative to establish the seminars. A committee of top scientists should elect a chairperson and discuss and suggest to management the best format for the seminars and the role that our consultants can play in them. Whatever the format, the seminar must require active participation and exchange, it must not be a lecture where people attend passively. A favorable research environment must offer worthwhile objectives, recognition of successful scientists, rewards for technical achievements, freedom of inquiry, continuity of programs and must be encouraged by an understanding management. A responsive management can make it flourish and an indifferent or hostile management can destroy it in a short time.

The success of this strategy, according to Mino, required a management commitment toward hiring the best people, ideally through the new Discovery Research Department at Stamford, under the leadership of a talented director.

For the future, there must be a long-term objective and an intensive effort to hire the best people available. During the past decade the ranks of our best scientists have been seriously depleted, due mainly to unwise and inconsistent management policies that turns research off and on following favorable or unfavorable business cycles or due to the particular mood of the men on top. We lost several outstanding scientists at Stamford in the early seventies and were unable to replace them. We not only lost these creative minds, but their leaving the company had a negative effect on those who remained.

In recent years we have been unsuccessful in hiring the best people from the best schools. This failure is due in part to our salary offers which were too low and in part to our programs that failed to spark the interest of these people. We must be prepared to make offers outside our guidelines in special situations to attract outstanding people. The best recruiting ground for CRD should be the Discovery Research Department, led by an inspired and well-known Director and staffed with a number of outstanding scientists. This department should be the hub of CRD research and should provide the right environment and the long-term programs that attract outstanding young scientists. As they mature, some of these people will choose to grow scientifically along the scientific ladder, others will get interested in shorter range product research and will move to other departments, thus providing a source of high caliber, innovative research people for CRD.

It is important that we appoint an outstanding man as Director of Discovery Research because this man will have to exert an influence not only within his department, but must coordinate long-term projects throughout CRD. To find this man and to convince him to accept the job is going to be a difficult task that will require time. We should not be discouraged by initial failures and be prepared to invest time to get the right man, rather than settle for second best.

Contributions to R&D Programs

Most people interviewed said that in the past, scientists were not encouraged to contribute ideas to long-range programs. As a consequence, most of them do not see this as part of their job or at least not a very important one. Obviously, the first step is to emphasize the importance that CRD management places on the participation of scientists in the preparation of long-range programs. We must emphasize that CRD is evolving along a different path, that the expectations of management have changed and that new ideas are not only welcome, but essential to any successful long-range research effort and that they will be rewarded.[52]

When Mino looked into the reasons for loss of interest in research, he observed that "[t]here is agreement between management and the technical people interviewed that research productivity has declined in recent years following decreased motivation and innovation in research and, I will add, lack of initiative in the commercial departments." For Bound Brook, as Hardy had suggested, "the most often mentioned demotivating factors during the interviews" were "unwillingness of management to start work in new areas. The chemists understand that work in certain areas such as dyes is not profitable for the Company and understand the need for discontinuing such work. They do not understand why work cannot be started in new profitable areas. All they see is a continuous decay of R&D activities (at Bound Brook) with no effort to enter other fields."

As for remuneration: "Money only becomes a demotivating factor if the people do not make enough and are really concerned about it … Money alone does not motivate in the face of an unfavorable environment. At present people are not so much concerned about money as they are worried about job security, especially at Bound Brook."[53]

Mino had harsh words for the profit centers

that segment the corporation artificially into small units that are managed according to short-term objectives. Here the shoe fits. Since Cyanamid is in the specialty chemicals business, whether we like it or not, our profit centers are many and small … This type of organization engenders even more devastating effects because it is incapable of responding to competitive challenges that derive from major innovations in products or manufacturing processes. To be sure, the profit centers are highly flexible and capable of responding quickly to customer needs in existing markets, but they do not see the need for long-term research and development of radically new technologies.[54]

In summary, "the fragmentation of the Chemical Divisions into small profit centers and the systems used within the Company to fund R&D, is responsible for the short-term programs and a major cause of low research productivity."[55] The complex technological system was run not on the basis of science or engineering but on "parochial interests." The system of funding did not meet the long-range needs of the corporation, since it "lacks a driving force to plan and work for the future and must be one of the most important factors in preventing Cyanamid's growth in the chemical business." Moreover, the profit centers "consistently assume the passive role of a critic, very rarely the active role of a contributor. This state of affairs exists in OCD and in many departments of ICD [Industrial Chemicals Division]. This system of R&D sponsorship leads not only to short-range research, but causes lack of continuity in the research effort; when the centers are pressed for higher earnings they have an incentive to cut back research." The conclusion was that failure had nothing to do with R&D itself, but only with how it was managed.

To overcome this difficulty, Mino suggested the introduction of a system in which R&D resources would be allocated to profit centers on the basis of potential profits; the centers would then compete for R&D funds. He also discussed an earlier proposal that new product introduction might be facilitated by "granting R&D both accountability and authority," though acknowledging that this would "meet a lot of resistance within the Chemical Divisions and perhaps at the Corporate level." Mino closed on a note of cautious optimism by drawing attention to earlier successes in novel technology that had been brought about through the right type of collaboration at Bound Brook.

> Once a new product reaches the stage where sales development and initial production are needed, R&D must be heavily involved with the person or team responsible for sales development, and manufacturing people must assist in the pilot plant or in the interim facilities to inject their experience and learn about the new product first hand. This is how the Plastics Additives and the Synthetic Elastomers [Numa Spandex] were developed at Bound Brook in the sixties; by a full cooperation between research, marketing and manufacturing. This must be the common goal and the only path to success. It was done before, it can be done again.[56]

It is perhaps significant, in the light of Mino's comments, that one of the last dedicated research activities carried out at Bound Brook, well into the 1980s, was in the area of plastics additives.

Conclusion

American Cyanamid was not alone in feeling the wind of change from the late 1950s. It was widely recognized in the chemical industry that: "The disappointing lack of really novel innovations since 1950 has been a major cause of our recent failure to maintain the impetus of growth."[57] In 1980, Edward G. Jefferson, DuPont's new chairman and chief executive officer, drew attention to other factors: Expensive energy and hydrocarbon feedstocks since 1974, the need for modernization, global competition, and environmental control.[58] Moreover, electronics and life sciences had taken the "glamour" out of chemical industry. Research and development declined everywhere in the 1970s, and when it was revived in the chemical industry during the 1980s the main focus was on pharmaceuticals and biologically interesting molecules. As elsewhere, the process, and management, of innovation had been reinvented.[59]

Between 1960 and 1980, there were strong, and sometimes risky, responses in the chemical industry, particularly among the United States counterparts of American Cyanamid, with failures and successes in abundance. Sometimes this depended on the idiosyncrasies of management or research leaders; or on sheer luck brought about by diversification that enabled a firm to apply its skills to a new or related technology. At other times, it was the decision to get out of one line of business, perhaps because the marketing or research organizations—or both—failed to identify or produce the right products. In the case of American Cyanamid, this last path was followed. Dyes, then related chemicals, were abandoned, while the rapid ascent of pharmaceuticals and agricultural products underscored the metamorphosis into a life-sciences company. Despite the strong dependence of other divisions on the OCD products, the major casualty of this transition at American Cyanamid was to be Bound Brook, with its great emphasis on aromatic chemicals, particularly intermediates, colorants, and rubber products.

Free-time research, introduced in 1954, was scrapped by senior

American Cyanamid management at Wayne in 1976. It was considered again at the end of the decade when there was an urgent need for suggestions that might lead to a revival in innovation. For Bound Brook, however, there would be no new motivational strategies, only demise in research activities, a general staffing level rundown, and transfer of the facility to the Lederle Laboratories Division.

Isaiah Von opines with regard to research strategies and technical innovations that it "was the conduct of the General Managers from around 1960 that did more to destroy the plant than anything else."[60] As already stated, it is Erwin Klingsberg's view that after the 1950s research suffered because the people in control were "generations of faceless bureaucrats ... Science management became unbelievably poor." There is further evidence of such problems contained in reports in the chemical press around the time that Cytec was spun off. The new management, consisting mainly of former American Cyanamid personnel, was openly critical of the way that Cyanamid's top-heavy management had run the chemical/fine chemical operations.

There is no question, though, that when it came to R&D, scientists, managers, and company leaders—at American Cyanamid and elsewhere—were wandering in a corporate wilderness during the 1970s (and even earlier) and 1980s as they attempted to satisfy objectives laid down by poor market analysts, impatient marketing departments, and accountants. Vast sums were spent on R&D, and academic consultants were brought in on an unprecedented scale, but all to little or no avail. It was the end of a golden age that harked back to the traditions laid down by Heinrich Caro at BASF and others in the dye industry. It took new attitudes, perceptions, and cross-disciplinary approaches—for many, nothing less than a jarring shift in perspective—before R&D saw a revival in the chemical industry, through research reinventing its own management systems and moving in the direction of life sciences.

In August 1978, Salsbury advised colleagues in a memorandum dealing with management of innovation that: "Substantive corporate changes will have to be made to demonstrate commitment on the part of corporate management. Policies which inadvertently restrict creativity will have to be identified and changed. For example, the statement that Cyanamid seeks to grow within the framework of its 'existing businesses' should be withdrawn."[61] Fortunately for American Cyanamid, it had inherited all the essential elements for developing a comprehensive plan that would smoothly take the corporation into the life sciences: the research tradition from Calco, pharmaceutical expertise through Lederle, multidisciplinary approaches at Stamford, and agricultural expertise. Increased R&D investments started in 1979, but not at Bound Brook, which had no place in the new era. The new Discovery Research Department at Stamford was the major beneficiary.

The Bound Brook obituary, at least as far as aromatic chemistry went, appeared in the form of a passing remark in the 1984 American Cyanamid annual report to stockholders stating that certain unprofitable lines had been eliminated. The same report also referred to the creation in 1981 of "a four-step research fellows program to recognize Cyanamid scientists who demonstrate exceptional performance."[62] The objective reality was that heavy and traditional chemicals were out, and American Cyanamid, after spinning off Cytec and leaving just Lederle and Princeton, would transform itself into a pharmaceuticals, biomolecular sciences, and agricultural biosciences business. One observer commented: "If the company continues to invest in research and development and avoids the illegal activities that have proven so costly in the past, this corporation will maintain its good standing in the worldwide chemical industry."[63] At the beginning of the 21st century the emphasis had shifted again, away from life sciences and agrochemicals, toward human pharmaceuticals, at American Home Products (since March 2002 known as Wyeth Corporation).[64]

Chapter 9

Industrial Hygiene and Toxicology at Calco

"[Y]our first patient with a severe methaemoglobinaemia will most assuredly startle you."—Arthur F. Mangelsdorff, "Methaemoglobinaemia—Recognition, Treatment, and Prevention," *Industrial Medicine and Surgery* 21 (1956): 395–98, on 396.

Working conditions at Bound Brook, in common with many chemical facilities, particularly those engaged in making dyes and intermediates, were not altogether salubrious. In addition to the constant care required in handling strong acids and alkalis, and toxic reagents such as phosgene, there were several other potentially hazardous or unpleasant aspects of dye-making activities, notably in the processing of the tons of spent iron from reduction processes. It is to the credit of the facility, or loyalty of the workers, that there were only two major work stoppages at Bound Brook, one in 1941, and the other in 1962, neither of which was connected with hygiene matters. Another that began in December 1978 did raise health issues, but did not bring the factory to a standstill.

Certainly by the early 1930s there was a strong emphasis on worker safety at Calco, maintained through a Safety Committee and incentives for shops to minimize work-related accidents. In 1930, Calco could with some justification declare that the

> interest of the management in the quality of its products, is equaled only by its interests in the welfare, safety and happiness of its family of workers ... Much thought and expense have been devoted toward safeguarding the employees against accident, toward providing the cost of modern sanitary and healthful working conditions and toward encouraging the individual advancement and welfare of each. Locker rooms, bathing facilities, a restaurant with low prices, a completely equipped and manned First Aid office provide for the health and

safety of employees in the plant ... Furthermore, the men of the managing group project their interest beyond the gates and into the very homes of their industrial family. Cooperation looking toward economy and saving for the home is offered. Free group life insurance, contributory aid for additional life insurance and sick benefit, and educational training are available. And, as a tribute to the humane spirit and further expression of full confidence, a good proportion of the employees have availed themselves of the opportunity to participate in Calco Chemical profits by purchasing Company shares. A fine spirit of harmony exists between employees and management.[1]

The Calco fire protection engineeer until his death in 1932 was A. H. Smith. His replacement, from 1933, was Albert Fletcher Hutchinson, who in 1935 was placed in charge of safety at Bound Brook. At that time there were two medical officers: Donald O. Hamblin, M.D., who established the Medical Department, and his assistant, Arthur Mangelsdorff, brother of Mildred, who had gained his M.D. at Cornell in 1928, and joined Bound Brook in 1934. From 1937, the Medical Department was located in the then new building 10; hospital facilities were also introduced. Apart from providing treatments for accidents and various ailments, they enhanced worker productivity. Certain occupational illnesses were peculiar to the synthetic dye industry, and required careful attention, particularly cyanosis, brought about by exposure to nitrobenzene and aromatic amines.

Blue Lip

At Bound Brook, as at other places where aromatic intermediates were made and handled, "it was discovered that working with chemicals brought ills and injuries of a new character." In the United States until around 1920, generally whenever aniline, dinitrobenzene, or similar aromatics were made, "superintendents considered that their duty had been properly performed if they were able to get out the required production without more than 10 percent of their men continuously on leave and if such men as were left were able to at least stand up."[2] By the mid-1920s, the situation improved considerably, mainly due to an emphasis on cleanliness. At Calco in the 1930s, employees working with paranitraniline (made by nitrating acetylated aniline, or by selective reduction of *para*-dinitrobenzene) had to undergo constant examination. "After certain operations these men must take a shower and be inspected by a doctor. This rule usually makes necessary a daily examination of these employees. Records are carefully kept of these examinations. Pipe fitters and other mechanics, after having worked with tools and equipment that have been used with hazardous chemicals, must also take a shower and be examined immediately following completion of the job ... Cyanosis, 'blue lip' as it is called by the men, was a serious and ever-present danger during the early days." A man affected by cyanosis, methemoglobinemia, to give it its correct medical name, was a distressing sight, requiring quick action to prevent a debilitating illness, or even death.[3]

The blue coloration of skin typical of cyanosis indicates that the ability of blood cells to transport oxygen is destroyed. The condition was well known in the European dye industry in the 19th century, and occasionally encountered in the United States.[4] Incidences of "blue lip" became increasingly common at Bound Brook. Affected men were taken out of buildings and laid out on a bank in the open air to recover. A number of remedies were described in the literature, such as consumption of milk, but none were favored at Bound Brook. The routine examination of workers took place from around 1936. Health risks in buildings where workers handled aromatic chemicals for prolonged periods were minimized through the donning of protective masks and clothing.

In 1938, Food and Drug Administration regulations concerning exposure to chemicals were tightened up considerably following a case in the previous year in which a number of people had died in California after taking a syrupy preparation called "sulfanilamide elixir." The cause of death was poisonous ethylene glycol (used in anti-freeze) in which the sulfanilamide was dissolved. The toxicity of many chemicals found in the workplace received more attention, and a number of guidelines were promulgated. At Bound Brook, the cause of cyanosis was reexamined by Hamblin and Mangelsdorff, using the Hardy recording spectrophotometer, "a costly bit of apparatus." Their instrumental techniques showed how aniline and nitrobenzene produced methemoglobinemia, and provided a method for measuring the methemoglobin concentration of the blood that was valuable in treatment of the condition. After the study was published in 1938 it was considered to be definitive, and was widely cited for several decades by medical experts.[5] Hamblin and Mangelsdorff undertook annual medical check-ups for all staff at Bound Brook, and acted as their general practitioners, until embittered local doctors objected to the latter practice. In the 1940s, Hamblin was appointed medical director at the New York headquarters of American Cyanamid, from where he maintained contact with leading industrial hygiene experts. Mangelsdorff, president of the American Academy of Occupational Medicine during 1950–54, retired from Bound Brook in 1954.

The influx of unskilled workers into the plant, especially after 1941, raised more basic problems of worker health and safety. The Bound Brook *Safety Manual* for 1943 warned that: "Puddles, especially in chemical plants, are not always water. They may be a toxic or corrosive material, such as acid, caustic, or aniline. Do not step in any puddle." The Calco laundry played an important role in ensuring cleanliness and hygienic working conditions.[6] Albert Hutchinson's duties were soon extended to supervision of workmen's compensation, employment insurance, medical benefits, and hospital and life insurance.

Dangers from New Chemicals

In matters of industrial hygiene research, Calco had the benefit of its own laboratories, those at Lederle and Stamford that dealt with chemotherapy and toxicology, and outside experts. Inhalation, ingestion, and absorption studies, particularly of aniline and aromatic nitro compounds, were stepped up from 1941 in line with the great increase in wartime production. Some of these problems had already been encountered in munitions and dye factories during World War I. Old equipment worked beyond its capacity in structures that did not provide adequate ventilation for the unprecedented levels of output led to unsatisfactory and unhealthy working conditions. Continuous exposure to dusts and dry powders was often a cause of discomfort, and in some cases of severe illnesses. New products, and processes carried out on a large scale, introduced hazards of a largely unanticipated kind.

A well-documented example involved the death in February 1943 of Louise B. Bryant, a black worker of around twenty years of age employed in the Pharmaceutical Department. Bryant joined Bound Brook on November 23, 1942, and on December 17 reported a "hive-like" rash. On January 24, 1943, she returned home unwell. During the night of February 4–5 she died in Somerset Hospital. Her prior medical history indicated nothing unusual. Another black female worker in the same department became ill in April. Bryant had worked on the dryers for the intermediates 2-aminopyrimidine, or 2-aminodiazine (for sulfadiazine), and isocytosine, and the other girl had worked with 2-aminopyrimidine and 2-aminothiazole (for sulfathiazole). This suggested that the culprit was 2-aminopyrimidine. American Cyanamid, with its expertise and other resources for developing tests for chemicals, immediately investigated a possible causative link between the onset of illness and the deceased's exposure to this substance.

Liver damage was suspected and investigations into the possible role of the intermediates were undertaken at the Stamford Chemotherapy Laboratory. Animal experiments suggested low toxicity for 2-aminopyrimidine, with a possible toxic effect on the liver after prolonged administration. From June 1943, further toxicity studies, including of 2-amino-4-methylpyrimidine, were entrusted by Hamblin to Robert Kehoe and staff at the Kettering Laboratories of Applied Physiology, University of Cincinnati, College of Medicine.[7] In April 1945, Hamblin advised Kehoe that it "appears to me that we can reasonably conclude … that there is no evidence that 2-aminodiazine [2-aminopyrimidine] can be classed as a specific hepato-toxic agent … I would like to know whether or not you agree with this interpretation."[8] The court trial to establish the cause of Bryant's death from "acute yellow atrophy" took place early in 1946, when there was still no consensus concerning the toxicity of sulfa drug intermediates among certain manufacturers, namely American Cyanamid, Merck, and Abbott Laboratories. In August 1946, Dr. William Deichmann of Kehoe's laboratory discussed with Dr. R. M. Watrous, of Abbott Laboratories, a paper the latter had published in 1943 concerning the "hazards that attend the industrial handling" of 2-aminothiazole. Watrous advised Deichmann that through modification of the method of manufacture the severity of exposure had been reduced, and as a result no further symptoms of illness were encountered.[9]

Robert Kehoe's Kettering Laboratory also undertook toxicity experiments on American Cyanamid's methyl and ethyl acrylate, hydracrylic acid, trichloroacetonitrile, and cyanuric chloride (from 1943); fluorinated hydrocarbon insecticides, and DDT (from 1944); and ionac resins, paper resin 605, ammonium and calcium dicyandiamide, and potassium cyanate (from 1946). Kettering continued toxicity tests for American Cyanamid until 1949, though from 1948 all new work was placed with a laboratory in Virginia. The fluorinated compounds, as potential chemical warfare agents, were classified as secret by the U.S. government. Arising out of these studies were four Kettering publications in the *Journal of Industrial Hygiene and Toxicology* during 1948–49.[10] American Cyanamid continued to support the Kettering Laboratory's industrial hygiene research until 1960. Five years later Kehoe's studies on industrial exposure to lead, that suggested toxicity only at relatively high levels, came into question when Clair C. Patterson produced lead pollution studies demonstrating that very low levels in the environment were extremely hazardous.[11]

Air, Gases, and Dust

Atmospheric pollution was an ongoing problem at Bound Brook, affecting workers inside manufacturing buildings, where fine airborne particulate matter caused some of the most severe respiratory ailments. Several changes to processes had been introduced by the early 1940s, in part to satisfy irate neighbors. Certain obnoxious gases were recovered, particularly hydrogen sulfide and carbon bisulfide (disulfide) from the MBT process. One use for the recovered hydrogen sulfide was to convert calcium cyanamide into thiourea, an intermediate in the manufacture of sulfathiazole. Vat dye processes were modified in order to improve the working conditions. Thus the installation of absorbers removed the unhealthy dust accompanying purification by sublimation of anthraquinone. The important mercury-catalyzed sulfonation of anthraquinone was at first carried out by spraying the toxic metal into the reactor. The venting with air during this operation generated corrosive fumes of sulfur trioxide. This problem was overcome by addition to the reaction mixture of a soluble mercury compound.[12]

As an example of other concerns, Victor King in a paper to trainees drew attention to the problem of auramine manufacture, particularly the unsatisfactory way in which the product was isolated:

> In visiting auramine plants all over this country, as well as in Europe, it was obvious that the procedure was one unholy mess. Auramine is a unique dyestuff in that of one class of dyestuffs it is the only member that has any use in the world. It is made by a unique process and when it is made, it is in a kettle that is very hot, well over 180°C, and on hot, dry, dusty salt. These kettles were discharged onto the floor and operators were expected to march in and hoe this hot, dusty mess to cool it as quickly as possible. They all said you must do this because as any good chemist who knows his theory knows if you drowned such a charge in water you would ruin it as water destroys auramine and converts it into ketone. However, no man and no equipment could last very long in such a frightful, miserable, unhealthy and corrosive atmosphere of hot, dusty salt, ammonium chloride and ammonia, not to mention H_2S, so our idea was to drown these charges in water. We were told "it can't be done." In fact, the better plants used to have special steel cooling platforms to drop the charges onto, and ventilating systems to remove the fumes. Well, we drowned the charges anyway and still do. We knew the same theory they did, but we also knew that water is a very unique chemical itself ... and ... has a perfectly enormous ability to absorb heat; and cold water doesn't destroy auramine very fast. In order to develop a decent, satisfactory manufacturing cost and eliminate a working condition that no self-respecting man ought to have to work in, we knew we had to stop discharging these hot kettles onto the floor.[13]

Calco chemists modified the process—by drowning the charges in water—and transformed the working conditions: "Since that time others have adopted the same procedure."

Improved industrial hygiene conditions, and better understanding of processes, were much needed, as was readily admitted by the management when it created the Industrial Hygiene Department, a function of the Medical Department, around 1950. Moreover, the focus of the Medical Department in 1957, two decades after its founding, had changed considerably: "*Perhaps the greatest single step* *forward has been a change from merely treating an injured worker to that of placing the emphasis on prevention.*" [italics in the original] The department had "grown from one full-time physician to our present staff of four full-time physicians and from one full-time nurse to 12 nurses. A few years ago an Industrial Hygienist was added to the staff ... An important part of the medical program is performed by our clinical laboratory. This is under the direct supervision of a well-trained medical technologist. We can now perform all the necessary diagnostic laboratory tests which our doctors feel are indicated. This laboratory is also approved by the New Jersey State Dept. of Health to perform serological blood tests."[14]

The Medical Department developed elaborate precautions to prevent occurrences of several illnesses, including cyanosis. Employee exposure was monitored, with instruments, by four industrial hygienists, under W. R. Bradley, chief, Industrial Hygiene.[15] A test for aniline in the air, based on diazotization and coupling with H-acid, measured concentrations of the amine down to one part per million. When the level of aniline reached unacceptable levels in a production building, the Engineering Department was brought in to design an improved system of ventilation.[16] By the 1960s, the Bound Brook medical facilities, still located in building 10, were under the control of three doctors.

Despite all precautions, fatal accidents occasionally took place. In one instance, a process involving nitrobenzene ran out of control, there was an explosion, and three operators were killed. The correct procedure for bringing the reaction under control was, apparently, not followed.[17] Less hazardous, but of concern, was the manner in which a large pyramid of elemental sulfur was stored in the open, posing the risk of acid formation when it rained, or of an explosion due to the low ignition temperature of a dust cloud.

Carcinoma

The greatest workplace hazard, however, came from bladder cancer among workers engaged in the manufacture and handling of certain intermediates. Papillomous disease of the bladder, often called "aniline cancer" (after the aniline dye industry), had first been observed among dye workers in Frankfurt in the 1890s, and later also in Basel. The suspects were aromatic amines, particularly beta-naphthylamine, and, later, benzidine, both first made on a large scale from the 1880s. The time delay between exposure, metabolism, and development of a tumor meant that the onset of bladder cancer was generally not observed for at least a decade. In the 1930s, DuPont had undertaken considerable research into this and related problems.[18] At that time the main culprit was found to be beta-naphthylamine, though attention in Europe also focused on benzidine. At Bound Brook, warnings were distributed by the Medical Department in 1939. In the 1940s, Hans Lecher told Erwin Klingsberg that I.G. Farben's policy around 1930 was to employ older men in its beta-naphthylamine manufacturing plants, so that the cancer would show up only later in life, preferably, as far as the company was concerned, after retirement of the workers. King and colleagues obtained information about the toxicity of beta-naphthylamine from German chemists in 1946, and also from Montecatini and DuPont. In July 1947, shortly after it was agreed that a start should be made on beta-naphthylamine manufacture at Bound Brook, Mangelsdorff distributed a cautionary note:

> Recently we agreed to the production of four batches of Beta-Naphthylamine, with the understanding that urine examinations be made on the men frequently ... Before we decide to continue the manufacture of Beta-Naphthylamine, I think we should consider some of the facts that we have found so far.
>
> First, to date we have exposed forty-five men to the manufacture of Beta-Naphthylamine. Each one of these men may develop a bladder tumor in the course of the next ten years, and if he does, I feel that we are responsible for the production of this tumor and that he should be compensated for it according to the existing statutes. Second, some of the men working in the production of Beta-Naphthylamine, who did not show red blood cells in their urines, are now showing them singly and in clumps. This to me means that we are getting some absorption of Beta-Naphthylamine and some bladder irritation. I would suggest that all of these men by cytoscoped in the next three months, in order to determine whether or not they have any lesions in their bladders.
>
> With these facts before us, I believe we must consider whether or not we can afford to assume the risk involved and if we can, then can we make Beta-

Naphthylamine; if we cannot, I do not think we should manufacture any more of it.

As for the areas in which Beta-Naphthylamine is used as an intermediate in the production of our various dyes, handling of the material should be thoroughly investigated and so engineered that the operator will have no contact with the material.[19]

The amine was studied in considerable depth at the end of the 1940s by medical experts at ICI's Dyestuffs Division (Blackley) and at CIBA's Clayton Aniline, both of Manchester, England. Bladder cancer was also detected among a number of workers at French dye factories in the 1940s. In 1951, participants at a conference held in Basel discussed the prevalence of bladder cancer among dye workers. During the following years, T. S. Scott, of Clayton Aniline, published the definitive studies on cancer induced by aromatic amines, which included recommendations for modification of manufacturing plant in order to minimize exposure.[20]

Beta-naphthylamine was used at Bound Brook from 1936 until the mid-1950s. From 1950, the urine of employees was routinely examined for the presence of red blood cells. Checks were made for the presence of beta-naphthylamine as contaminant in alpha-naphthylamine and certain naphthalene-derived intermediates.[21] From 1961, workers handling alpha-naphthylamine were also examined, now by the PAP cytology test. In the mid-1960s, following an investigation in England sponsored by the Association of British Chemical Manufacturers, general manufacture of the alpha isomer was abandoned because it invariably contained traces of beta-naphthylamine. The alpha intermediate was also no longer purchased by Bound Brook. It was last used there in 1972. Calco made the benzidine-derived Congo red from the late 1930s until 1942, and other benzidine dyes until 1971–72, when most U.S. manufacturers ceased producing these colorants.[22] At one stage, to avoid dust exposure, benzidine was handled only as a wet solid. The first recorded case of bladder cancer at Bound Brook was in July 1961. From 1969, workers handling benzidine also underwent the cytology test. By the end of the 1970s, seven cases were considered as occupational. Considerable concern also arose over 4-aminodiphenyl, a carcinogen found in waste from the diphenylamine process. In May 1978, after it was found that trace amounts had concentrated in the refining still, Cyanamid was cited for "willful violation" of the federal standard.

From 1970, when Congress passed the Occupational Safety and Health Act, toxicological and ecological challenges were confronted by all U.S. dye manufacturers. Employers were expected to provide workplaces free of known hazards, particularly toxic chemicals. Screening and evaluation of new and untested chemicals, studies on threshold exposure that caused sensitization, and of effective doses that interacted with target organs, became major occupations for analysts and toxicologists. In 1971, the Stanford Research Institute (SRI), under contract with the National Cancer Institute, began work on a system for ranking chemicals by their estimated hazards, particularly aromatic amines, naturally-occurring carcinogens, and inorganics.

From the Occupational Safety and Health Act there emerged two administrative bodies: the National Institute of Occupational Safety and Health (NIOSH), within the Department of Health, Education, and Welfare, whose purpose was to engage in research and provide regulatory recommendations to the second body, the Occupational Safety and Health Agency (OSHA), within the Department of Labor. When later in the decade NIOSH turned to investigations of potential carcinogens that included several used and made in the dye industry, the American "Dye Industry ad hoc Committee on NIOSH (carcinogen project)" was established. Its first meeting was held in New York on June 16, 1976.[23] The preamble explained that the events and background leading to the meeting included publication of a list of "58 potentially carcinogenic substances for which NIOSH has a project to review and consider recommendations for workplace standards," and a planned meeting with NIOSH to determine the significance of the project and to discuss the inclusion of a large number of the dyes on the list. The dye industry's NIOSH committee and the Synthetic Organic Chemical Manufacturers' Association (SOCMA) established a joint Ad Hoc Dyes Ecology Group, which first met on December 2, 1976. It worked in conjunction with the American Dye Manufacturers Institute, Inc. Bound Brook's Dr. Samuel M. Gerber, manager of Dyes and Chemical Research and Development, Chemical Research Division, during 1975–80, represented American Cyanamid at the June and December inaugural meetings.

Malcolm Kenneth Orloff, marketing manager, Color, Textile and Intermediate Chemicals Department, was also present at the December meeting. Gerber played a prominent role in furthering the investigations.[24] Passage of the Toxic Substances Control Act of 1976, drawn up on the lines of the 1938 Food and Drug Act, led to a focus on both worker and consumer exposure, though in time the impact was less far-reaching than originally intended.

The growing concern over the environmental impact of dyes and chemicals used in their manufacture had led to the founding in Europe during 1974 of the Ecological and Toxicological Association of the Dyestuff Manufacturing Industry (ETAD). The U.S. dye industry's response was a body similar to ETAD, the Dyes Environmental and Toxicology Organization, Inc. (DETO), founded in 1977. The enrolment meeting, chaired by Gerber, was held on April 14, 1977, and attended by two other Bound Brook representatives, also from the Color, Textile and Intermediate Chemicals Department, George Manolakis (dyes product manager), and Herb A. McKenzie (manager). DETO established a classification task force; a literature research program concerning the toxicity of dyes was discussed with the consultancy firm Arthur D. Little, Inc.[25]

Worker anxiety over exposure to carcinogenic and toxic chemicals was raised at Bound Brook during a strike by 1,300 employees belonging to Local 111 of the International Chemical Workers Union that began early in December 1978 and lasted 52 days. Prominently displayed on one placard near the entrance to the works was the question: "Is this the entrance to Cancer Alley?"[26] To such concerns, plant manager Eldon Knape is said to have commented that "[w]e don't run a health spa."[27] In the summer of 1978, awareness among shop floor staff had been heightened when, as part of a project in occupational health and safety, two medical students from the Albert Einstein College of Medicine, Howard Hu and Jack Quarrier, interviewed thirty Bound Brook workers on health issues. The students' results, including the statement that "[c]arcinogens are a very serious problem throughout the Bound Brook plant," were featured in the *Bergen Record*, but only after a response giving details of protective clothing, process changes, and precautions, was received from the American Cyanamid management.[28] Publication was withheld until after the strike was settled.

On January 8, 1979, while the workers were still on strike, the *Courier–News* published an editorial highly critical of conditions at the Bound Brook facility. Retired chemist Neil Mackenzie responded, in defense of the company, that the

> editorial, "Major health effort needed at Cyanamid" is an unfair reflection on the thousands of Cyanamid employees both salaried and hourly who have worked so hard to make the Bridgewater plant a safer and healthier workplace. They have committed themselves to a "major health effort" over the past 60 years. They have pioneered in the development of safe and healthy working procedures in the chemical industry. The success of this effort is a matter of record. Your references to the two product citations by the Occupational Health and Safety Administration do not prove that there has been a breakdown in health and safety emphasis. Just the opposite is true. The plant handles thousands of different products. The fact that only two citations were given, one for each of two minor products, is an admissible accomplishment for the employees.[29]

The citations, one of which was for the 4-aminodiphenyl, had no doubt done much to sensitize the workers more than ever before to the potential health risks posed by the wide range of chemicals used and generated at the site.

DETO and ETAD exchanged information, but despite their similar interests did not merge since DuPont was against sharing classified information with its European competitors. Only after DuPont left the dye industry, in 1981, did DETO become part of the ETAD organization. By then, American Cyanamid was in the final stages of abandoning its colorant-making facilities at Bound Brook.

Chapter 10

Waste Treatment and the Future of Bound Brook

"American Cyanamid, Bridgewater Township, is the largest source of water pollution in the Raritan River."—Steven. L. Gordon, deputy attorney general, New Jersey Department of Environmental Protection (NJDEP) to Richard Sullivan, commissioner, NJDEP, July 21, 1970.

The condition of the Raritan River downstream of Calco had been a problem since the 1920s. In the mid-1970s, following enforcement of strict environmental regulations, it was to have a major bearing on discussions over the future of the Bound Brook facility. The situation warranted the production of a special prospectus outlining proposals for improved liquid waste treatment and other works. This prospectus, dated February 1975, was typical of documents drawn up at American Cyanamid in support of new projects, and presented by divisional presidents to senior executives. They varied in length from 50 to 150 pages, and began with an introduction by the president, followed with technical information, economic and financial data, arguments for new projects, and, where appropriate, endorsement from other divisions. Whereas individual presidents of divisions could approve expenditures of up to $0.25 million, more costly projects had to go before the executive committee's management and finance staff, made up of all the corporate officers. If exceeding $20 million, as in this case, they required approval from the board of directors, consisting of the General Staff and outside directors.[1]

This 1975 prospectus, introduced by Organic Chemicals Division president Ben H. Loper, recalled the history of waste treatment at Bound Brook, the situation at the time of writing, the status of tertiary wastewater-treatment studies, and the need to dispose of sludge from the secondary (biological) treatment process. The content provides a useful preliminary perusal of the main issues covered in the second part of this study. It also constitutes a first-hand impression of American Cyanamid's perspective as it struggled to satisfy state and federal agencies, and meet the demands of a 1973 stipulation and consent order. Loper's summary of the early history of liquid waste treatment began with the inauguration of the first, or primary, treatment process that became operational during 1939–40.

During the late 1930s, the New Jersey Department of Health established a requirement for the treatment of industrial wastewater which would prevent the discharge of acidic wastewater to the river. In order to meet this requirement, a primary treatment plant was installed at Bound Brook at a cost of $500,000. This plant consisted of a 21 million gallon composting basin in which the combined plant waste stream was mixed by natural means to level out the composition of this effluent, a lime neutralizing station where lime was added to produce a neutral effluent and a 60 million gallon settling lagoon in which the solids, essentially inorganic, resulting from neutralization were removed by gravity.

This was followed with development of a secondary, or biological (activated sludge) treatment plant, that became operational in 1958.

In 1949 it became apparent that more extensive treatment to remove the dissolved organic matter would be necessary. Extensive laboratory and pilot studies were undertaken which, over a period of 10 years at a cost of $1 million, led to the design of an activated sludge secondary treatment plant. This facility was constructed at a cost of $4.5 million and placed in operation early in 1958. For 1975, the operating cost for primary and secondary treatment is estimated to be $2.8 million. In 1958, an agreement was reached with the Somerset-Raritan Valley Sewerage Authority (SRVSA) to provide secondary treatment for 5 million gallons per day (mgd) of their primary treated wastewater at cost. The SRVSA, located 300 yards north of our secondary plant, provides primary and some secondary treatment for municipal waste generated in Somerville, Raritan and Bridgewater, serving a population of 45,000 and several industrial plants. This agreement will be terminated in 1977, at which time the SRVSA will have completed their own facilities for secondary treatment of all wastes.

The secondary effluent discharge to the Raritan River fulfilled the requirements of the New Jersey State Department of Health during the years of operation that the design criteria were not exceeded. However, with the continual increase in production and corresponding increases in both organic loading and hydraulic flow, it became apparent in early 1966 [following passage of the federal 1965 Water Quality Act and the 1966 Clean Water Restoration Act] that an improvement in the BOD [Biological Oxygen Demand] removal efficiency would be necessary to meet the more stringent requirements established by the State Department of Health. From a critical evaluation of various Dissolved Oxygen (DO) and ... BOD parameters in the activated sludge aeration basins and the Raritan River, it was concluded that the secondary treatment facility would have to be upgraded to provide a BOD removal efficiency approaching 95%. A program was developed to accomplish two objectives, namely, to determine the quantity of additional oxygen required to upgrade and optimize the secondary treatment facility and to select and design the aeration facilities for this additional oxygen.

In 1969–70, 18 75-hp surface aerators were installed at a cost of $766,000 to supplement the oxygen supplied by the existing diffused air system. We have achieved an average annual BOD removal efficiency for 1971 through 1974 of 93% versus an average of 76% for the period 1967 through 1970.

Increasingly stringent regulations concerning water quality led to a civil action brought against American Cyanamid by the Department of Environmental Protection of the State of New Jersey, on May 17, 1972, "alleging that the discharge of treated effluent from the Bound Brook Plant resulted in violation of certain water quality criteria including toxicity to fish, color, floating solids (foam), suspended solids (sludge), and dissolved solids." The outcome, on October 12, 1973, was a stipulation and consent order, whereby Cyanamid "agreed to conduct laboratory and/or pilot plant work to develop" an advanced wastewater-treatment process, based on activated carbon.

It was further stipulated that the plant was to be completed in July 1976 and placed in operation in October 1976. An important result of the Consent Judgment is that the Bound Brook Plant need not meet the generally applicable New Jersey Surface Water Quality Standards, including low dissolved solids limits in the river. No economically feasible means to meet these dissolved solids limits is known.

Effluent standards for our discharge are to be established on the basis of a pilot plant demonstration utilizing the process selected for installation. Analysis of samples to be taken during this run will provide the data on which to set these standards. Eight quality parameters are to be measured including dissolved solids. The standard for dissolved solids will be based on our normal operating level which will include beta-naphthol manufacture and thus should be met with no difficulty in the future when beta-naphthol is transferred to Willow Island.[2]

... Our secondary treatment plant removes 93% of the BOD or biologically degradable load present in our wastewater versus a State requirement of 90% removal. *The wastewater after secondary treatment, however, contains a substantial amount of nonbiodegradable dissolved organic substances* [emphasis added]. Thus, the net reduction of total organic carbon (TOC) is 65%. The average daily discharge to the river of such non-biodegradable organic compounds constitutes the source of pollution responsible for toxicity to fish, color and foam.

The substances present in our treated wastewater which are toxic to fish have not been specifically identified. In order to identify the compounds present in the treated wastewater, we should be faced with the need to separate and identify many thousands (estimated more than 5,000) of organic compounds and then determine the toxicity of each of these compounds to fish. The magnitude of such an undertaking would require many man-years of difficult analytical work plus fish bioassay tests on the compounds identified and success is improbable. A University of Wisconsin team was asked to analyze the polychlorinated biphenyls [PCBs] in our wastewater and gave up because of the many interferences present. A study of this kind would then lead to the need to trace the sources of those substances found to be toxic back to the individual process. This could be a very difficult undertaking, since many compounds present in the wastewater before secondary treatment are biologically oxidized to other substances in the secondary treatment plant. Such a program was not undertaken because the time required for study was not compatible with State and Federal timetables for compliance, it would have been too expensive, manpower could be better used elsewhere and the likelihood of success was not favorable.

The biotas tests conducted on the effluent presently discharged to the river from the secondary treatment plant have shown acute toxicity to the fathead minnows. The fathead minnow is used by the State to evaluate fish toxicity in the Raritan River. In these tests there was a 100% kill rate of fish even at dilutions of 20–30% of treated effluent in river water. Similar tests using the effluent from our activated carbon [tertiary] pilot plant have shown survival rates in undiluted effluent comparable to or better than the intake river water. Removal of these nonbiodegradable organic substances is thus related to fish toxicity as controlled by the State and is controlled by Federal regulations contained in our NPDES [National Pollutant Discharge Elimination System] Permit [issued to American Cyanamid in November 1974] through an effluent limitation on COD (Chemical Oxygen Demand), which is a measure of the dissolved organic substances remaining after wastewater treatment.

Tertiary treatment using granular activated carbon is the best way (and there is no other feasible, economic way) to remove nonbiodegradable organics in order to meet State and Federal requirements. It will remove color, foam, odor, etc. Furthermore, the Consent Judgment between the State and American Cyanamid Company specifies installation of a carbon plant to remove toxic substances.

The other serious environmental problem that impacted on the condition of the Raritan was the accumulation of waste activated sludge from secondary treatment, some of which was released to the river. This made necessary the installation of a suitable incinerator.

The activated sludge secondary treatment plant generates sludge at a rate which is a function of the BOD load which in turn varies with production cycles. Unless this sludge is removed from the plant, it will carry over to the river in amounts of suspended solids exceeding our NPDES Permit. Disposal of excess activated sludge has been a chronic problem for the Bound Brook Plant for several years. From 1958 to 1965 the sludge was stored in an earthen lagoon with lime added to prevent the sludge from becoming biologically active. However, we were unsuccessful and the lagoon became a source of very unpleasant odors, a condition responsible for frequent complaints from nearby residents. It was finally covered with soil in order to eliminate the odor. A second attempt to store activated sludge in a lagoon was also similarly unsuccessful. This sludge was excavated and trucked to barges for ocean disposal. For the past year [1974–75], we have pumped about one-sixth of our excess sludge to the nearby SRVSA for dewatering and incineration in their facilities. The rest has carried over with our treated effluent to the river, to the displeasure of the State. The SRVSA plant has limited short-term excess capacity, which we are utilizing at a cost of approximately $10,000 per month.

Our NPDES Permit requires nearly complete removal of suspended solids from our treated effluent beginning in October 1976. This will necessitate disposal of six times the waste activated sludge than has been possible using excess capacity of the SRVSA system. We have considered future plans of the SRVSA for expansion of their facilities but found no timely basis for a joint arrangement to handle our sludge even in the unlikely event [that] satisfactory financing and services could be established. The SRVSA sludge incinerator, when expanded, will be smaller than the Cyanamid treatment facility. SRVSA sludge handles and incinerates easier than Cyanamid sludge.

The account then turned to the primary waste-treatment plant, which incorporated a pumping station, a 36-inch diameter wooden pipeline, and neutralization and settling lagoon facilities. This also required upgrading, particularly increased capacity.

A common gravity sewer system collects all process effluent, sanitary waste, cooling water, and rainwater runoff throughout the plant. The wooden pipeline from the pumping station to the treatment plant has been patched recently. If it broke, the whole site would be shut down.

When it rains, the sewer system will hold about one million gallons, equal to one-third of an inch of rainwater runoff. The pumps and pipeline can pump about one-fifth of an inch of rainfall per hour in addition to the normal process load. A one-inch per hour rain is quite common. As a consequence, when it rains the plant sewer is occasionally diverted directly to the river to prevent plant flooding. This means the highly acidic (pH 2), toxic, tea-colored raw sewage liquor flows directly into the river about five to six times a year. The EPA is requiring us to halt this practice.

Therefore, it is proposed to supplement the existing Building 98 pumping station with a new pumping station. Both will be fed from a new electrical substation with power feeds from two independent sources. It is also proposed to replace the 36-inch pipeline with a larger line to carry the higher volume from the additional pumps.[3]

There followed a brief description of pilot-plant studies for the proposed activated-carbon wastewater-treatment plant, with emphasis on the economic importance of regeneration of spent carbon, and operation of the full scale plant:

The Consent Judgment ... required us to conduct laboratory investigations and pilot plant studies using activated carbon to upgrade the quality of the Bound

Brook secondary effluent. Both granular activated carbon (GAC) and powdered activated carbon (PAC) processes were evaluated during an extensive pilot plant program conducted over a 21-month period from October 1972 through August 1974 ... Data collected during two 3-month studies [of controlled addition of powdered activated carbon to the aeration chambers of activated sludge units] indicated that the du Pont PACT [Powdered Activated Carbon Treatment] process would require exorbitant carbon dosage rates, which were neither economical nor practical, in order to produce an effluent comparable to that obtained using granular carbon.

The wastewater now discharging from the existing secondary treatment clarifiers will be first collected and pumped through four multimedia sand filters to lower the concentration of suspended solids to acceptable limits that will not clog the carbon beds. The discharge from the filters will then be pumped through ten 16-foot diameter by 65-foot high carbon bed adsorbers, which remove dissolved organics (adsorbate), expressed as units of TOC [Total Organic Carbon]. The adsorbers will be sized and operated in such a manner as to maintain no more than 25 ppm of TOC in the 20 million gallons per day discharging from these units. Spent carbon from the adsorbers will be recycled through a regeneration furnace to remove adsorbed impurities and restore the carbon as nearly as possible to its original adsorption capability. The water discharged from the adsorbers will be aerated, chlorinated in the existing chlorination unit, and then discharged into the Raritan River.

Final effluent specifications will be set with the New Jersey Department of Environmental Protection by analysis of the results of the pilot plant demonstration run, to be started in the late first quarter 1975. A toxicity testing program will be run concurrently with the demonstration run to determine acceptable levels of contaminants in the effluent. It is our best judgment at this time (based on experimental evidence) that a TOC level of 25 ppm and a suspended solids level of 10 ppm will meet toxicity criteria.[4]

The report revealed that seventeen alternative systems, including distillation and reverse osmosis, had been considered for installation at Bound Brook by Zurn Industries, Inc., an environmental and engineering construction firm, but all were rejected in favor of activated-carbon adsorption. The TOC test and problems of sampling were then discussed.

The test for TOC is relatively fast and straightforward whereas the test for

BOD (biological oxygen demand) is lengthy, unwieldy, and less precise. Both are used in waste treatment plant load calculations. In 1965, a program was commenced to analyze effluent from each process for TOC by sampling the waste streams. This data gathering continued through 1974.

In December 1974, the data for the most significant 250 out of 450 streams sampled were available for comparison and tie-in with the overall values measured at the present waste-treatment plant. The results showed the data were not of sufficient reliability to use in load projections. To get a representative sample of effluent is difficult.

A computer material balance analysis was then made of carbon lost in the processes. Based on 1974 estimated actual yields (which became 1975 standard yields), this was adjusted for losses through vented gases and solid sludges trucked away. The remainder should represent the TOC in the liquid effluent ... Thus, the material balance data were considered usable for TOC load prediction.[5]

The manufacture of beta-naphthol—a considerable contributor to effluent—and certain derivatives, including Schaeffer's salt, were scheduled for transfer to Willow Island in 1975. The remaining top 50 TOC contributors accounted for 77.4 percent of the measured TOC (in 1974). Since plans were afoot to move levamisole production from Bound Brook to Puerto Rico, and introduce new low-pollution processes for nigrosine and Tobias acid, "it was assumed for the purposes of this prospectus only that all dyes except the profitable basic dyes, solvent dyes, Nigrosine, and certain selected vat dyes (Jade Green, Olive T, Brown R and Orange T) would be discontinued."[6]

To meet these objectives, a number of probable expansions, additions, and shutdowns at Bound Brook were reviewed, including: in 1975, shutdown of existing beta-naphthol and mixed acid facilities; in 1977, replacement of the nigrosine plant, and opening of the new Tobias acid plant; and in 1979, shutdown of the Catan aniline operation. These were offset by planned expansions, including of: Cyanaprenes (1975); crude Cyan (phthalocyanine) blue and azo pigments, surfactants, and Cyanacryl (1976); refining facilities for antioxidant intermediates, sulfas, and thiazole accelerators (1977); bulk pharmaceuticals (which required the greatest expenditure), AO2246, and new alkylation facilities for antioxidant intermediates (1978).[7]

On March 27, 1975, following review of Loper's prospectus, the

Board of Directors of American Cyanamid approved an allocation of $22.4 million for a new tertiary (activated carbon) wastewater-treatment plant and an incinerator for disposal of spent sludge from the secondary treatment plant.

Chapter 11

Conclusion to Part 1

Large-scale dyestuff manufacture in the United States was the nation's first faltering step into the modern organic chemicals industry. It was the outcome of a random and external event, the outbreak of war in Europe in 1914. That war, it was believed at first, would be quickly over. When by the spring of 1915 it became apparent that this was not the case, American manufacturers realized that they were about to face long-term shortages of many imported products, particularly German-made dyestuffs. The creation of the Calco Chemical Company was one of the earliest responses. Typically, its founders did not know the first thing about dye making when they decided to enter the business. In order to avoid pollution problems with neighbors in Somerville, they were obliged to seek out a remote location. They found a suitable site on the Raritan River near Bound Brook, where intermediates for dyes and, from 1917, explosives were produced. After the war, the talented, ambitious, and forward-looking experts and entrepreneurs who presided over the factory began the large-scale manufacture of dyes and other products from their aromatic intermediates, drawing in part on the experience with military-related technology, and benefiting from acquisition of the adjacent government plant.

Though there are gaps in the historical record for the early years, the contemporaneous accounts and reminiscences of Victor King and John McMurray provide a sense of daily life and an adequate impression of the challenges and excitement that accompanied the making of complex organic chemicals. Despite the sometimes difficult learning curve, nothing seemed to disturb the basic purpose of the Bound Brook facility, nor of its energetic founder, Robert C. Jeffcott, and his chemists, engineers, and managers. It was, by all accounts, a pretty smart, even if struggling, manufactory by the mid-1920s, when its activities were financed with funds raised by a bond issue. Calco was a pioneer in science-based chemical innovation, sometimes out of desperation rather than desire. Then, at the end of the decade, the remarkable chemical undertaking almost ran out of money.

Calco's savior was American Cyanamid, which, despite its origins in the nitrogen business, and with a particularly strong emphasis on the manufacture of agricultural chemicals, embarked on a series of aggressive acquisitions aimed at diversification at a time when many uncertainties faced the agriculture sector. Calco, in early 1929, was its most significant catch, though other dye and intermediate firms were also purchased around 1930 and merged with Calco. The acquisition spree would soon turn American Cyanamid into a behemoth of invention, inspiring awe and respect.

The growth of American colorant technology impacted many walks of life, through textiles, paper, and the new plastics based on Calco's amino resins. During the early 1930s, these resins satisfied the urge for greater use of color in domestic, workplace, hotel, restaurant, and shop environments. Coal-tar dyes and pigments colored plastic molded crockery, lamp holders, and radio and clock cases as well as wallpapers, fabrics, and paints. Pigments contributed to both form and function in the new age of streamlining that began around 1930 and dominated design, particularly in transportation systems, during the second half of the decade. It was an era in which advertising came of age. Paper-coloration and paper-printing technologies improved, permitting low-cost production of high-quality colored wrappings and cartons, four-color half-tone reproductions, and full-color posters, advertisements, and magazine covers using inks based on coal-tar pigments.

Once American Cyanamid became a leading manufacturer of dyes—the third largest in the United States by the late 1930s—it increasingly diversified into other organic chemicals, many based on the very same aromatic intermediates. These moves were facilitated by entry into: heavy chemicals through the acquisition of Kalbfleisch; phthalic anhydride, through Selden; biologicals and pharmaceuticals, through Lederle; surgical sutures, through Davis & Geck; and the design and construction of chemical plants. No less significant was support of research and development, the acquisition of new technologies that were improved by innovations at Bound Brook, provision of university scholarships, and investment in training of new graduate employees. High scientific training maintained the technical endeavors that commanded respect at home and abroad. American Cyanamid scientists were thoroughly engaged in their professional communities, were prolific contributors toward the professional literature, and were closely involved with review and abstract services, for both internal use and leading chemical and technical journals.

Bound Brook was well equipped to convert aromatic intermediates into sulfonamide, or sulfa, drugs, and products for retardation of rubber deterioration and acceleration of vulcanization, as well as to create the novel amino resins based on melamine-formaldehyde condensations. To achieve the latter, the facility developed the first successful industrial synthesis of melamine in 1939, starting with calcium cyanamide.

Unlike DuPont and the other major U.S. chemical manufacturers Calco became prominent in both polymers and pharmaceuticals. Its product range was probably the broadest of any U.S. chemical manufacturer. Through this legacy, American Cyanamid was enabled to focus on the reciprocal and interactive connections between chemical and polymer sectors, forged through tremendous growth in resins and plastics, and cross-fertilization between chemical and pharmaceutical—and later life science—R&D activities.

New business areas and technologies provided opportunities for those with ambitions for promotion, as well as power struggles, infighting, and probably petty jealousies, between organic chemists involved in pharmaceuticals and dyes, and between organic and physical chemists (though the details are mainly unrecorded). Meantime, Calco proved that science-based chemical industry brought in its train considerable earnings-per-share growth. The message was not lost at 30 Rockefeller Plaza in New York, headquarters of American Cyanamid. In 1937, the Bound Brook way of doing things was transferred to the new Stamford research center. Structural changes, particularly the creation of corporate divisions, and product and service departments and their later reorganizations, accompanied inventive growth, including the move into resins, plastics, and fibers. There was a brilliant record of planning and execution of major projects, even if some were innovative in a "copying sort of way." Research results made available through a liberal publication policy won tremendous acclaim for Bound Brook in the scientific community.

In 1939, the Calco Chemical Company became American Cyanamid's Calco Chemical Division. By then the chemical industry was a leading emblem of American commerce. The outbreak of World War II brought new challenges. It also brought to the fore the issue of national and international cartels, particularly shenanigans in the chemical industry. From 1941, Calco, mustering all resources of organizational skill and a pool of extraordinary technical knowledge, stepped up production of melamine resins, sulfa drugs, dyes, pigments, and intermediates for explosives. Patriotism, professionalism, and tremendous output, the results of long hours, tough working conditions and certainly some danger, earned the strategic facility at Bound Brook its four-star Army–Navy E pennant. During and after the war major advances in instrumental methods of quality control, color matching, and analysis were made at both Bound Brook and Stamford. These innovations were the heralds of a revolution in analytical techniques. From 1946, German discoveries studied by Allied commissions contributed to other technical achievements, including vat and fluorescent dyes and polyurethane resins. These were followed with acrylics and new textile and paper chemicals.

In the early 1950s, it was decided to scrap the old management structure, under which certain sectors had been run as "fiefdoms." Parts of American Cyanamid, particularly Calco, were split into new divisions, each with its own management, answerable to the General Staff. This reflected the way many executives already thought about their business units and departments. In the 1954 restructuring, Calco became the Organic Chemicals Division of American Cyanamid, soon with operational headquarters at Bound Brook, where other divisions were also important players. It marked the end of an era of scientist-managers, those who had hitherto played the major role in decision making. Research that for the previous decade or so had been tightly controlled by men such as Hans Lecher, who instilled the traditions of the German-style research institute, with all its its inherent advantages and—sometimes—disadvantages, according to who was in charge, was now conducted differently. Long-term exploratory research of a more general nature was separated from the focused short-term departmental objectives "responsive to profit centers" that measured performance in terms of revenues and dealt with the firm's more immediate needs.

Bound Brook's diversity meant that it served as the best training ground for potential managers, though once their talents were proved they were moved elsewhere. From the late 1950s, the management culture began to change. As a result, there were some periods when individuals with little or no previous experience in the processes and products associated with Bound Brook were transferred to the site, often in anticipation that they would bring about improvements. Furthermore, major decisions on resources, equipment, research, development, and working methods were made by corporate executives also without scientific training in Bound Brook technologies. Their job was to oversee the staff of several thousands and approve budgets for millions of dollars. Approximately one-quarter of American Cyanamid's 16,000 employees were associated with the Organic Chemicals Division. Mainly, but not always, divisional presidents came up from the ranks of marketing departments (though generally with technical backgrounds).

Efforts to foster innovations that contributed to business growth, based on matching marketing objectives with R&D, met with far less success than in the past, though the problem was not unique to American Cyanamid. Just as DuPont, confronting similar difficulties, continued to rely on growth and income from nylon, so American Cyanamid, though to a lesser extent, placed its faith in melamine resins. From around 1960, there appeared to be less interest in the discoveries of research scientists at Bound Brook. That again was an industrywide problem. It was not always clear that a new invention would provide a profitable product, particularly in the mature fields of dyes and polymers. In contrast, some innovations, such as electrochromism, and proposals for diversification into the biology-based sciences, were ahead of their time, and did not seem to justify instituting new policies. As patents ran out, and developments continued to lag, dye companies increasingly depended on cartels to sustain margins, which invariably meant that scientists became less important in the boardroom.

Cost cutting meant job losses, in 1971 for the first time among Bound Brook research laboratory staff. Erwin Klingsberg, in his telling, believes that the managers, including men with extensive scientific and technical capabilities, had been forced to give way to the rule of what he calls "bookkeepers," or the business school influence.

Richard Madison opines that there was a total lack of confidence in Bound Brook research. The situation was not helped when inexperienced high flyers from outside with bold ideas about modernization and efficiency forced through manufacturing changes in totally inappropriate ways. What they were trying to do was bring down the cost of operating a highly competitive, mature, and capital-intensive business. The outcomes were a mix of cost overruns and general confusion, with, more than once, a disastrous chain of miscalculation. As Von explains, American Cyanamid went about the design of the continuous azo dyes process—as well as designing changes in processes for intermediates—in such a hurried manner that it compromised on the things that Bound Brook had done so well. The accounts and correspondence of these and other participants in mid- to late-20th-century chemical industry, and the opportunity to discuss and record their views, certainly provide an unparalleled, firsthand picture of life at the Bound Brook facility, including the difficulties it confronted after 1970.

Klingsberg and Madison were not alone in deploring the absence of corporate executives that understood chemistry and chemical engineering. From their perspective—and with strong echoes of the economist John Kenneth Galbraith—while top executives knew about marketing and returns on capital invested they knew very little about what American Cyanamid produced. Constraints and ambiguities abounded, and the corporation was paralyzed by a too-heavily centralized and inept organization. There was no comprehensive plan for research or development, nor the willingness to trade the available options against each other in order to achieve solutions acceptable to people who did not share the same criteria of judgment.

However, this is only half the story. To the extent that interviews carried out for this study have captured versions of experiences that privilege certain perspectives and points of view, we must consider the other half.

That other half involves not only successes, but also the challenges facing an encumbered industry. From around 1960, scientists and engineers at Bound Brook did introduce several new processes with considerable success, such as the continuous reduction of nitrobenzene that first saw application elsewhere in the Organic Chemicals Division, and the *ortho*-benzoylbenzoic acid process for vat dye intermediates. The same applied to glyoxal and phosphine processes, as Jay Leavitt recalls. The glyoxal process, though originally licensed, "had to be developed in-house. Phosphine and all its derivatives was an in-house' project." Leavitt concedes that "we probably spent too much time on the anthraquinone, beta-naphthol and isocyanate processes, and the electrochromism and reactive dyes were unsuccessful in the end." But, he emphasizes, "I never felt that new research ideas got short shrift."[1] Likewise, Hardy emphasizes that "research was generally supported by the divisional presidents."[2]

From the perspective of senior management, American Cyanamid had to adjust its strategy to new circumstances, struggle with competition from abroad, and come to terms with the fact that, maybe, existing research programs, particularly at Bound Brook, were obsolescent, had adhered to anachronistic traditions, or, more seriously, had been poorly managed. They had to opt for the most expedient way to improve the balance sheet. By the 1970s, there is no question that the attitude toward skilled and experienced human resources, particularly lack of status, and even downgrading, reduced morale in the laboratories, narrowed the pool of talent, and brought about outcries over the way in which research was conducted. There was no balance between the need to look for new ways of bringing money into the company and the need to take risks. The somewhat conservative advice of business and marketing consultants, brought in to assess operations and products, was followed. The working environment at Bound Brook was improved, and attempts were made to find creative ways of staying in the same lines of business or of getting out altogether. The warren of early-20th-century buildings was torn down, and extensive renovations and improvements, and modernization programs, were inaugurated.

Certain critical areas of modernization, however, foundered. Almost unworkable or unprofitable continuous and semicontinuous Tobias acid and nigrosine processes replaced "perfectly good batch operations." The situation was not helped by problems with Willow Island's new beta-naphthol process, on which Bound Brook was reliant. They turned out to be expensive mistakes that brought about the abrupt demise of colorant manufacture at Bound Brook during 1980–82.

Those interviewed for this study, capable and often outstanding scientists and managers alike, acknowledge that while until the mid-1960s there seemed to be no limit to the chemical industry's prospects, the subsequent decade and a half saw a loss of hegemony, followed by painful consolidation, and not just at American Cyanamid. The reasons they give for the failure of Bound Brook are several, quite apart from the difficulties of modernization. Mainly, however, the different perspectives arise from the fact that, following a long period during which American Cyanamid scientists routinely made great advances in inventions and innovations, some industry-leading, there were very few new discoveries that could be brought to the market place. This undermined support for research, at least for the way it was conducted. DuPont also suffered greatly, losing "faith in scientific research" as well as in its dyes business.[3]

Research and its management came under the closest scrutiny. Research strategies and the general approaches of management were not always in accord. Hardy echoes the feeling of many others:

> Not surprisingly, some department managers (a step below divisional president) tended to focus too much on short-term results. I also believe that the management philosophy which held that a manager could run any operation, even if he had no background for the job, caused failures. In a broad sense, the Bound Brook operation functioned well for twenty years after World War II, but increasing competition from Europe and Japan where new and more efficient plants had been built made our operations non-competitive. Unfortunately the overall management (particularly the executive committee) had not developed a strategic plan capable of meeting the challenge in the chemical area, although life sciences were early recognized. The research and development departments (the overall research function) cannot be absolved of all responsibility for this failure. Cyanamid entered the polyester business at an early date. If more plans had been made and resources devoted to the plastics field [including additives, film and molded products, as well as fibers and other polymers], we could well have been a leader competing with companies such as Dow and GE today.[4]

Philosopher of technology Steven L. Goldman, who has undertaken in-depth analyses of the workings of U.S. industrial enterprises, including the causes of failure and success during the last quarter of the 20th century, finds that the responses from American Cyanamid personnel at various levels fit exactly his depiction of innovation as driven by institution-specific managerial decision making. According to Goldman:

> An endemic problem then and still is that bench scientists and engineers are almost never participants in strategic business decisions affecting innovation and so lack a "big picture" view of the company and its daily activities. Thus the bench people can feel that senior management has no interest in what they're doing. What they experience is ignorance of resource allocation decisions determined by business strategies set by executives at the top. Technical knowledge is a resource pool that management selectively exploits in support of business strategies, not because new knowledge must be converted into innovations.

Goldman emphasizes that: "Today there is much more of an effort to give personnel at all levels an understanding of how their operations fit into the 'big picture' strategies of the company."[5]

Apart from attitudes toward research management, as Isaiah Von explains, there were more wide-ranging reasons why Bound Brook's decline was perhaps inevitable.

> The site also happened to be on a flood plain, which caused major problems over the years, including a catastrophic flood in August 1971 [Hurricane Doria] which caused $17m worth of damage ... Beginning in 1964 suburban growth began and after a few years houses began to appear all over the area and in one area to the northeast about a mile away in the hills there were some fancy developments. The residents there did not hesitate to complain about odors that came their way ... but [between the Johns-Manville asbestos plant] and Calco and a little further down the river Union Carbide (formerly the Bakelite facility), the Raritan became heavily polluted. In the '20s people still swam in the river but by 1946 it was a sewer. Pushed by the state and later by the federal government the river was gradually restored, ending in the tertiary-treatment plant, but at very high costs. Air quality also had to be corrected.
>
> There are factors that were not the responsibility of the management. One, of course, was the gradual decrease of tariff support during this period. The other was the plant site selection and expansion: By 1946 there was absolutely no more capacity and further expansion was carried out at the new Willow Island facility. Another problem due to location was the inability to attract

good quality labor. Unlike DuPont's Deepwater plant, where there is not much competition for quality labor, from about 1960 on, this became a severe problem for Bound Brook. All around us pharmaceutical plants sprang up. Their plants were nice and clean, such as those of Johnson & Johnson, Squibb [both of New Brunswick], and others. Our shops were for the most part old and dirty. People who wanted to work in the chemical industry would tend to pick the more modern plants, so we were left with the dregs.[6]

So as to the question of what killed Bound Brook, it is possible to suggest a number of answers. Apart from those relevant to the U.S. dye industry in general, there were occasional massive misjudgments, often arising from the institutional structure and the corporation's culture and organization. American Cyanamid believed that it was doing the right thing, and, in the 1960s and 1970s, had the means to make new processes more efficient. However, certain new computerized and continuous technologies were either just not thought out sufficiently, or were at best premature—and in one case at least was botched. Others were never given time to fully develop, and often gave products that were inferior to the older batch processes. The people who understood the way processes worked were pushed aside. The design philosophy resisted the input of their information. No doubt the replacement processes could have been improved if more time had been spent on evaluating their problems. Maybe, in any case, staying with the old technology and many of its products was a mistake, since various external factors were changing the demand for Bound Brook colorants. These were the sort of difficulties confronted from the mid-1970s by OCD presidents Ben Loper and Jerry Forlenza—both with good groundings in American Cyanamid technologies—while contending with the need to reduce excess capacity, improve commercial activity, and comply with environmental requirements. Management brought in what promised to be exciting new technologies, but they could not be implemented. American Cyanamid was torn between the past and the future.

Forlenza correctly points out that, contrary to the opinions of consultants in dye making, the level of competition in the late 1970s made investment in colorant manufacture totally unrealistic. To take just one example, consider nigrosine. In this case, as Von recalls, the anticipated surge in demand never materialized after a Japanese competitor began manufacture in the United States. Moreover, the burden of complying with environmental regulations in New Jersey was aggravated at Bound Brook by the location next to a relatively small river and the need to install a costly advanced wastewater-treatment plant.

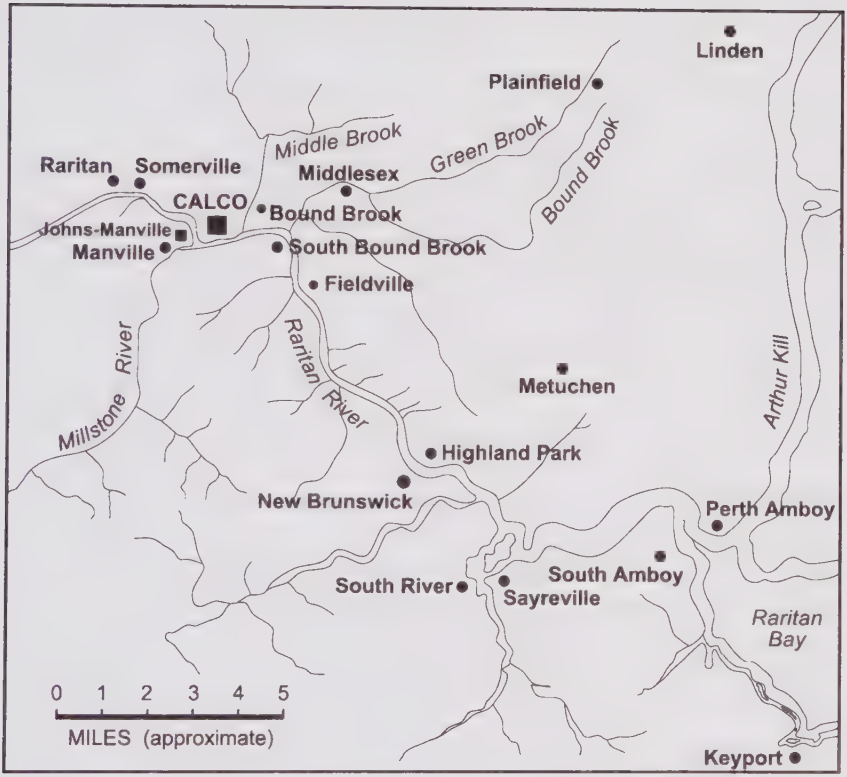
If this study provides a lesson, learned in hindsight, it is one that is all too familiar in the chemical industry. By understanding failure, it is sometimes possible to learn better how to succeed, or at least how to avoid costly mistakes. The failure of the naphthoquinone-to-anthraquinone process was not that it did not work, but that nobody took time to assess its inherent difficulties at an early stage. As Vanderwaart suggests, the debacle could have been avoided if an outside technical expert had objectively and professionally reviewed the facts. When it came to searching for ways to increase sales and widen markets, the manner in which recommendations from outside consultants were accepted and applied was not always the best nor the most appropriate. Thus modernization of technology sometimes proceeded without taking into account the opinions and advice of production managers with decades of learning in the course of experience and a coherence of background knowledge. By 1980–82, it was in any case too late to put things right. Modernization and downsizing did not work, and the tremendous competition from foreign firms and environmental regulation became stumbling blocks when attempts were made to sell the Bound Brook factory to other dye manufacturers in the early 1980s.

Yet despite the history of latter-day shortcomings, American Cyanamid did succeed, though only after the metamorphosis into a life-sciences corporation. In the early 1990s, when what was left of Bound Brook had become a branch of Lederle, the decision was made to break up the corporation into two units: chemicals, in the form of Cytec, spun off in 1993–94; and life-sciences, agricultural, and consumer products, American Cyanamid, acquired by American Home Products in 1994 (now Wyeth Corporation). The dye-making roots were played down as new high-technology products were offered to customers and used to attract investors. Though Bound Brook was the major casualty of American Cyanamid's new business strategies, historically its early involvement in complex science-based innovations, particularly the pharmaceuticals that were derivatives of dye intermediates, ensured that the facility played the key role in bringing about the ultimate move toward newer pharmaceuticals and life sciences. Bound Brook became the vanished symbol of the modern evolution of the U.S. chemical industry.

As explained at the outset, this volume covers the story of the Bound Brook factory from its establishment in 1915 to its run-down condition around 1980 by drawing on a number of themes central to the historiography of chemical industry—themes of process, strategy, and tactics and, what is no doubt the most neglected feature, the interaction with the environment, including handling and treatment of unwanted products, the waste of manufacturing processes. The history of the latter comprises Part 2 of this study. It receives considerable prominence here not only because it is almost completely absent from earlier histories of the modern dye industry, but also because it will be of interest to those still engaged in the industry, which has tended to expand in Eastern Europe and Asia as it expired in western nations.

Many chemicals connected with dye manufacture are non-biodegradable (biorefractory), or break down with difficulty, thus, for example, consuming much oxygen when released into natural waters. The same problems of difficult wastes arise wherever the industry operates without installation of adequate waste-treatment technologies. It is a complicated story that deserves serious exploration. At its end, we see that this was one area in which American Cyanamid technology was well in advance of that adopted by other corporations engaged in the manufacture of aromatic chemicals.

PART 2



The Raritan River and tributaries, including location of Calco

Adapted with permission from a figure appearing in Sheppard T. Powell and James C. Lamb III, "Industrial and Municipal Cooperation for Joint Treatment of Wastes. I. Industry Approach and Position," *Sewage and Industrial Wastes* 31 (1959): 1044–52, on 1046. Copyright 1959 Water Environment Federation.

Chapter 12

Calco and the Raritan River: An Environmental Problem

"Disposal of industrial waste waters in America is a challenge to industry never before fully recognized until recent agitation energized state water boards, initiated regional stream pollution authorities and provided governmental control centred in the U.S. Public Health Service."—Floyd W. Mohlman, "Disposal of Industrial Waste Waters," *Chemistry and Industry,* June 30, 1951, 550–1 (from abstract of a paper presented before the Society of Chemical Industry at its annual general meeting, London, July 15, 1951).

Introduction

The years between the second and the sixth decades of the 20th century were not only the period of greatest expansion at the American Cyanamid Bound Brook facility but also the time when the severely degraded conditions of rivers in the United States, particularly those in industrial regions, came to be judged according to new environmental and sociopolitical values. In manufacturing society, a certain level of aquatic pollution and air and land contamination was accepted as inevitable. Concern over the environment was generally restricted to wildlife and the wilderness. That was the case, in the minds of most people, until the early 1960s. Then, on March 1, 1962, a few months prior to the publication of the first installment of Rachel Carson's *Silent Spring* in *The New Yorker,* President John F. Kennedy presented his landmark conservation message to Congress. A year later, Secretary of the Interior Stewart Lee Udall was preaching the "Conservation Challenge of the Sixties," which censured industry for the fact that "most of our rivers today are a national disgrace."[1] This was a major turning point in the attitude of politicians to the impact of industry on the environment.

Increasingly the federal Public Health Service came under criticism for its inaction, and even for turning a blind eye to industrial pollution, at least until the threat of a new and rival water protection agency geared it into action in 1963.[2] As historian John K. Smith has pointed out, federal powers were enhanced in 1964 when President Lyndon Johnson passed the Civil Rights Act, which diminished the rights of individual states.[3] This was followed by two important federal acts, the 1965 Water Quality Act and the 1966 Clean Water Restoration Act. President Richard M. Nixon (1969–74) approved the establishment of the Council on Environmental Quality, the Environmental Protection Agency (EPA), and the passage of various conservation measures. These moves reflected the public's strong sentiment for a prolonged assault on polluters. They were to have far-reaching implications for many sectors of the chemical industry, whose history after 1970 was considerably determined by regulations concerning the storage, treatment, and disposal of its waste. In 1970, incidentally, American Cyanamid's Clifford Siverd was appointed by Nixon to the newly created National Industrial Pollution Control Council.

While problems of releases of waste to the environment were studied well before the 1960s, and certain regulations had been invoked to combat pollution, industry had not previously been confronted with such forceful state and federal legislation, including charges of criminal negligence. Further, nowhere was legislation developed and imposed against industry more rigorously than in the State of New Jersey, which passed a number of landmark laws, some that became models for adoption by the EPA. The impacts of the compliances on the industries of New Jersey were tremendous. The body of state regulations forced new approaches to all processes for producing aromatic colorants, including the handling and processing of intermediates, solvents, and finished products.

In the second part of this story, the Calco/American Cyanamid Bound Brook facility provides us with what is certainly the most appropriate case study in the United States of the impact on the physical environment of the manufacture of aromatic chemicals during the period of growth after World War I, the expansive years from the mid-1930s to 1960, and, as regulations became increasingly stringent, the final decades.[4] Several American-owned dye-making firms ceased this line of business completely after 1976. During the following twelve years, U.S. dye-manufacturing capacity, including in foreign-owned factories in America, was reduced by 150 million lbs., which, in 1976 sales terms, represented a loss of 60 percent.[5] Among the influences on business decisions to withdraw from this sector were poor profitability following the impact of the 1970s oil shock and increasing imports of dyes and textiles as a result of tariff reductions. There is no question, however, that environmental regulation played a prominent, and sometimes even the principal, role in the decision to quit dye making. The period of rapid decline started around 1980, after which four major factories in New Jersey—DuPont at Deepwater Point, American Cyanamid at Bound Brook, GAF at Linden, and the Swiss-owned Toms River facility—stopped dye manufacture altogether. Of the large American-owned firms, only one, Crompton & Knowles, a relative newcomer, remained active in 1990, the year it acquired Atlantic Industries of Nutley.[6]

By affording extensive coverage to the effect of manufacture on the immediate environment of a single factory, a theme not previously integrated in a detailed way into histories of chemical firms, this study represents a departure in style and content. Previously, through deliberate compartmentalization, and even underemphasis, the environment has been kept quite separate from the usual historical narrative. As a subject of sustained interest it has been confined to professional publications that cater to audiences with quite different agendas, such as historical geographers and historians of the environment, or environmental activists.[7]

Perhaps the main reason for the supression of environmental issues is that lengthy accounts of the murkier side of products of chemical industry are not considered compatible with celebrations of its famous discoveries and spectacular breakthroughs. Certainly the environment hardly ever surfaces in conventional approaches to competitive advantage, except insofar as such advantage is seen to be sabotaged when firms are forced to spend large sums in order to abide by stringent environmental regulations.[8] But while this distancing is characteristic of the classics of chemical industry history authored by Williams Haynes and L(udwig) F(ritz) Haber, and of certain worthy studies made possible by corporate sponsorship; it has come to seriously limit historical understanding.[9] No doubt it has also contributed toward the anti-industry bias in the media and public domain, with chemical industry reduced to an object of resentment, as well as to the conflicting responses, beleaguered defensiveness, and even a sense of shame in the industry. It is for these reasons that no apology is made here for bringing both sides together in almost equal measure, even though the simultaneous focus on useful products and pollution invariably introduces strains of ambivalence. This will, however, serve to engage the attention of readers who might otherwise view histories of chemical firms with great suspicion. Moreover, through exploring a literal backwater of chemical industry, and identifying those who inhabited or visited it, we can afford a new status to research into some of the toughest problems of waste treatment in industrial society, and also appreciate the accompanying technological, engineering, and political challenges.

Even though documentary evidence for scholarly studies is sometimes hard to come by, interest in American chemical industry and the environment has grown dramatically over the last three decades.[10] It is certainly now recognized as an important aspect of the historiography of chemical industry. However, while retaining the appeal suggested by subtle overtones and imagery, dredging up the past demands a convincing and thorough approach based on less-familiar resources. These include state and federal legislative and regulatory documents, court proceedings, inspectors' reports, and surveys produced by consulting firms engaged to: study soil, surface, and groundwaters; evaluate technological choices; and implement and supervise the construction of waste-treatment facilities.

By their very natures, the state inspectors' investigations often began with nothing more than suspicions of offenses as defined by law. Olfactory and visual sensing were important in evaluating the conditions of surface waters, no less than extensive chemical, physical, and bioassay tests that afforded quantifiable criteria of water quality. Inspectors' reports were the first steps in ensuring that obligations borne by the state in providing permits for releases were implemented, and determining whether the terms of permits were met with adequate professional diligence. This included supervision of all measures needed to minimize risks and inconveniences to the public. The sense of detail is important in all these deliberations, and though making for arduous reading, it enables corroboration, and invites comparisons, with open literature and the offerings of industry lobbyists and corporate publicists.

Here we are confronted with versions of the relationships among the Raritan River, Calco, American Cyanamid, and New Jersey state agencies (federal involvement became important only after the mid-1960s) that drew from both sides of the factory berm and dike. Despite the often litigious nature of the proceedings between industry and state, there was cooperation, even if often contentious, and a certain synergy. We see, for example, how legislative and other pressures forced the provision of three generations of waste-treatment systems between 1940 and 1977. Their sheer sizes are worthy of note: from 1957 the largest biological treatment plant in New Jersey; and from 1977 the largest industrial activated-carbon wastewater-treatment plant of its kind, equipped with what was certainly the world's largest carbon-regeneration equipment. They were trumpeted as outstanding achievements of modern industrial wastewater and environmental engineering, and models for other American Cyanamid divisions and firms to follow.

The manufacture of synthetic dyestuffs and other aromatic compounds, including pharmaceuticals, involves reactions that are carried out in aqueous media or in highly stable organic solvents. The latter include high-boiling and refractory aromatic liquids such as nitrobenzene and trichlorobenzene, used extensively in vat-dye manufacture.[11] The processes generate both solid and liquid wastes, including intractable tars, and gases that escape into the atmosphere. The special nature of the waste from dye manufacture was well-known in the 19th century, particularly in France, Switzerland, Germany, and England, the original centers of production.

The Waste of the Synthetic Dye Industry

Pungent smells and reactions that give colored solutions, as well as the thrill of a little danger, are the experiences of childhood chemistry for most people. When this is translated by industrial enterprises into daily assaults on the senses of smell and sight—corrosive chemicals carried by the prevailing wind and visibly tainted waters flowing downstream—and large-scale handling and disposal of hazardous chemicals, the public perception invariably turns to fear. In the early 19th century lifespans were reduced, sometimes dramatically, by the releases from chemical factories. Specific regulations concerning emissions began with the English Alkali Act of 1863, aimed at stopping atmospheric releases of corrosive hydrogen chloride from alkali factories. An important outcome was a change in the method of manufacture, enabling recovery and use of the otherwise offending gas. By this time the synthetic dye industry had become established in western Europe, and was providing its own brand of environmental problems.

In Lyon, France, in the early 1860s, waste from the arsenic acid oxidation of aniline caused sickness and death among residents who drank water from wells close to a dye-making factory. In Basel, Switzerland, following cases of illness caused by poisoned well water, the soil, groundwater, and canal-bed contamination by both arsenic and aromatic waste from dye production was extensively investigated. It was clear that waste that had not been contained or treated seeped into the ground and migrated to underground water sources. Laws were invoked or passed to restrict the activities of dye makers. In England, government commissions were instructed to pursue the conditions of rivers that passed through areas of chemical manufacture. In response to these moves, and to minimize confrontations with state and municipal authorities, dye-making firms tended to relocate next to fast-flowing rivers, downstream of inhabited areas, using them as waste sinks. This created unsightly stretches of rivers, and brought about complaints of stenches and colored water and difficulties with fishermen. As the dye industry grew, the situation worsened. In order to defend the interests of the industry, its trade representatives and lobbyists argued that a polluted river was a small price to pay for the great benefits of employment and taxes that the factories paid. They also promoted, in Germany and England, the idea that sections of river should be sacrificed for the sake of the economy. Willful ignorance, and not a little official laxity, were widespread.[12]

Nevertheless, from investigations in England during the late 19th and early 20th centuries, there arose a widely adopted gauge of pollution based on biological, or nowadays biochemical, oxygen demand (BOD) that provided information about the ease (or otherwise) with which organic contaminants could be broken down.[13] The formal measure dates back to the British Royal Commission on Sewage Disposal eighth report of 1912, in which a "Royal Commission Standard" was established.[14]

In the United States, federal water-quality legislation was introduced when Congress enacted the River and Harbor Act of 1886, which was the basis of the Rivers and Harbors Appropriation Act of 1899 (Refuse Act). This forbade obstructions to navigation and dumping of any refuse, apart from municipal sewage, into navigable waters. Lawful discharge required a permit from the Army Corps of Engineers.[15] In the late 1960s, the refuse act was retrospectively invoked to regulate environmental discharges. If river basins lay in different states, or, as in the case of the Raritan, several counties, then sections of watercourses were subject to the control of different authorities, each with its own priorities in water quality and sewerage standards. The economic benefit of industry to an area was taken into account, including of chemical manufacturers reliant on water supplies for processing and cooling, as well as for effluent disposal. The condition of surface water was determined by the worst upstream polluter, which provided little incentive for downstream cleanup. This gave rise to conflicts of interests that were rarely resolved.

Some order was established in 1948, when Congress enacted the Federal Water Pollution Control Act, amended in 1956, 1961, and 1972. The 1972 amendment made necessary a federal waste-disposal license or permit for any discharge. Individual states established water-quality standards, according to designated uses. These standards, subjected to statutory and regulative powers, effectively replaced discussion of pollution levels. They also made necessary improvements in waste-treatment technologies. The Environmental Protection Agency (from 1970) was responsible for reviewing applications for permits filed with the Army Corps of Engineers. The Federal Water Pollution Control Administration, one of the bodies subsumed into the EPA, regulated effluent discharges from point sources, including industrial plants, and set both effluent and water-quality standards.

Water quality is determined by a combination of characteristics: physical, including color, opacity, and solids content; chemical, including pH and hardness; and biological, including the extent to which dissolved oxygen is consumed in the aerobic degradation of organic substances. Biodegradable organic materials can have an adverse impact on water quality through depletion of oxygen, particularly if the BOD is high and there is a sustained input into receiving waters. Rivers have a limited, natural capacity to assimilate many organic compounds, generally according to dilution. The BOD, since it refers to oxygen used in biological decomposition, affects the ability of rivers to support aquatic life. A number of organic compounds, however, including aromatic products and wastes of the dye industry, resist biodegradation, are toxic, and bioaccumulate. Typically these persistent, or untreatable, compounds have BOD values of zero. Thus both biodegradable and non-biodegradable organic substances, as well as metals and acids, contribute to water pollution.

Over time, as water pollution increases, populations of aquatic flora and fauna that are intolerant to pollution are replaced by more tolerant species. Deterioration can thus be measured, at least qualitatively, by observing changes in the groups of living organisms supported by a river. Deficiencies in dissolved-oxygen content are indicated by the appearance of pollution-resistant creatures, such as tubifex worms. Another, more exact, measure of a pollutant's effect in a receiving water is acute toxicity, which for a particular substance is the concentration that causes half the population of a test organism to die within a specified time. This is the median tolerance limit TL_m, equivalent to TL_{50}. (Toxicity is also expressed as the lethal concentration, LC_{50}, the concentration in the environment that kills 50 percent of a group of organisms, and lethal dose, LD_{50}, the concentration of a toxin that kills 50 percent of a group of test organisms.)

The Raritan River

Considerations of waste disposal played a role in determining the location of the United States dye-making industry. In the case of Calco, which was forced to leave Somerville not long after production of intermediates was started in 1915, the waste sink was the Raritan River. The Raritan drains some 879 square miles of north central New Jersey, including parts of six counties: Somerset, Middlesex, Morris, Monmouth, Mercer, and Hunterdon. The river mouth opens to the Atlantic Ocean some twenty miles downstream of the Calco site. The river valley at Bound Brook contains up to thirty feet of alluvial material. Close to the river on the former Calco property that bordered the Raritan for approximately a mile and a half, this consists of some twenty feet of clay that covers ten feet of sand and gravel. A little farther north, where manufacturing once took place, the Brunswick shale comes close to the surface and sometimes outcrops. Deep below is the Brunswick aquifer.

The Raritan, whose flow rate varied from 60 to 90 million gallons a day at Bound Brook, according to the time of year, supplied 95 percent of Calco's water requirements, taken just upstream of the factory. Downstream, the river received the facility's liquid wastes. Significantly, Bound Brook lay within 50- and 100-year floodplains, and torrential downpours often brought the water table close to saturation, and sometimes, when assisted by hurricanes, even brought about flooding of land, mainly from overflowing surface water. On three occasions during its years of operation, the factory was deluged with floodwater. In February 1920, "Calco experienced one of the worst floods in the history of this valley," which led to diversion of Cuckold's Brook. A dike was constructed in an attempt to prevent further flooding, and this was reinforced in 1936. However, on September 22, 1938: "Failure of the dike to hold the whip-lash of a hurricane" again caused the site to be inundated.

> Production was shutdown at 1:30 A.M. Steam was shut off from the tunnels and underpasses but the low pressure system was kept in operation to supply electricity for lights and for the river pump. At 5:00 A.M., the water was 17.8 feet above normal ... the water at the dike along the western edge of the property touched 22.1 feet over normal, which was also a new high. By noon the next day, production started again. Since the high water in February 1920, this flood marked the first time when all shops in the plant ceased operation at the same time.[16]

When in 1949 and 1955 there were further major deluges, the flood-protection measures were sufficient to protect the site. However, they were unable to hold in 1971, when Hurricane Doria swept through the area, and much of the factory was submerged.

Surface Water Pollution in New Jersey

During the 19th century, water quality in New Jersey was monitored by the New Jersey State Sanitary Association. A New Jersey potable water act was passed in 1899; from 1909, the State Board (later Department) of Health regulated discharges from sewage facilities. On July 7, 1931, the New Jersey State Department of Health (NJDH) served cease pollution notices on 14 municipalities along the Raritan River. In February 1932, two-year extensions of time were granted. Though the Public Works Administration (created in 1933) provided funds for sewage treatment improvements, only one municipality applied, at least until after decrees were issued in April 1935. (Leroy Forman and R. P. Johns, "The Regulation of Stream Pollution in the Raritan River Basin by the New Jersey State Department of Health," *Sewage Works Journal*, 12 [May 1940].)

Sewage and surface water regulations in New Jersey that impacted on Calco, as well as on Johns-Manville, Sherwin-Williams, and the municipalities, fell within Title 58, Chapter 12, Section 3 of the Revised Statutes of New Jersey. With the enactment of the new state constitution in 1947, the NJDH was given broad regulatory powers. Statutes relevant to the Bound Brook facility are here referred to as N.J.S.A. 58:11-10; 58:12-2; and 58:12-3.

In April 1965, the NJDH issued regulations, effective from February 1, 1966, stipulating that American Cyanamid wastewater from the Bound Brook facility released to the Raritan River meet F-W-3 criteria, that is, suitable for recreational but not for potable use.

In 1971, the environmental responsibilities of the NJDH were transferred to the New Jersey State Department of Environmental Protection (NJDEP). The NJDEP Division of Water Resources comprised prior functions and staff that included water pollution control, potable water, water policy supply, and water and wastewater operator licensing boards. In 1977, the New Jersey Water Pollution Control Act (N.J.S.A. 58: 10A-1 et seq.) and Water Quality Planning Act (N.J.S.A. 58: 11A-1 et seq.) came into effect.

The 1930s: Surface Waters and Industrial Wastes in New Jersey

New Jersey's industrial expansion had brought with it some of the worst ills of manufacturing, particularly polluted rivers. The cause was growth in population, with the accompanying discharges of domestic sewage, and releases from factories. In the 1920s, there were calls for collaboration between state and industry in the cleaning up of surface waters, as participants at a 1961 conference held in New York were informed. The latter event dealt with pollution entering Raritan Bay, the convergence of the Raritan River and Arthur Kill, a narrow body of water that extends north to Newark Bay. It was conference chairman Murray Stein, chief, Enforcement Branch, U.S. Public Health Service, who reminded the audience that collaboration in pollution abatement was not a new idea.

> It is indeed prophetic, I think, that as long ago as 1921 the United States Supreme Court, in the famous Interstate Pollution Case of New York against New Jersey, said: "We cannot withhold the suggestion inspired by the consideration of this case that the grave problem of sewage disposal presented by the large and growing population living on the shores of New York Bay is one more likely to be wisely solved by cooperative study and by conference and mutual concession on the part of representatives of the States so vitally interested in it than by proceedings in any court, however constituted."[17]

In the case of American Cyanamid Bound Brook, pollution abatement did turn out, in part, to be a story of proceedings in court: Cyanamid's representatives defended the company's actions in the face of accusations and demands from the New Jersey State Department of Health (NJDH); guidelines and deadlines were agreed, and if not met the attorney general's office found cause for complaint; disputes reached, and sometimes dragged on in, the Superior Court of New Jersey at Somerville; rulings were laid down concerning court orders, including a consent order; and, to gain time, American Cyanamid appealed. The issue, each time judged according to different standards, state as well as federal, was the quality of the Raritan River downstream of Bound Brook. What was to be done about the waste released to the river constitutes another part of the story. One part resounds within the other.

Calco originally disposed of waste from its manufacturing operations through a system of drains connected via open ditches to Cuckold's Brook, and thence to the Raritan River. During the 1920s and 1930s, the appearance of the Raritan downstream of Calco changed dramatically, arousing the ire of such diverse groups as the Pillar of Fire organization, the New Jersey State Department of Health (NJDH), the Bridgewater Board of Health, and, several miles downstream, the citizens of New Brunswick, the Middlesex County seat and home of Rutgers University.[18] Municipalities, as well as Calco, came under attack for the general lack of waste treatment, both domestic and industrial, along the Raritan. At Bound Brook, as at many points along the Raritan, fishing was a strongly followed pursuit that was increasingly threatened by persistent, colored and often toxic industrial releases.

On the general problem of industrial waste released into the rivers and streams of New Jersey, the journal *Public Works* opined that: "The industries should bear the major cost of development of practical treatment processes, but the State should have the power to direct investigations and conduct small experiments."[19] Dye manufacture afforded organic waste of such a persistent character that leading waste-treatment specialist Dr. Willem Rudolfs, with funding from the Chemical Foundation, undertook the examination of its impact on sewage sludge of the type associated with less-persistent domestic waste at the New Jersey Agricultural Experimental Station, New Brunswick, associated with Rutgers University.[20] Also, following recommendations made at the 1928 annual meeting of the American Society of Civil Engineers, a grant from the Chemical Foundation was secured to enable the establishment in the same year of the Federation of Sewage Works Associations, and the publication of *Sewage Works Journal*. This body became independent of the Chemical Foundation as the latter was run down in the 1940s.[21]

The growing environmental nuisance created by industry and lack of municipal treatment downstream of Bound Brook were addressed at a meeting held on April 11, 1930, at Somerset County Court House, Somerville. Present were representatives of several municipalities along the Raritan River and industrial plants using the river "as a disposal basin," including Calco's Stanley Warzala. Waldo S. Coulter, sanitary engineer, New York City, read his report on the poor condition of the river and suggestions for handling sewage.[22] A week later, the *Bound Brook Chronicle* announced "Raritan River Sewer Problem–Immense Sum Needed to Purify Stream Now Polluted."[23] Readers were advised that the Borough of Bound Brook and Calco had been repeatedly ordered by the NJDH to cease the pollution of the Raritan. Eight months later, on January 6, 1931, minutes of the NJDH recorded that Calco's waste was a threat to the inhabitants of the state. The department gave notice to Calco instructing it to halt the discharge of wastes by April 20, 1931. Moreover, Calco "shall make such disposition of the said trade wastes as shall be approved by the Department of Health." A firm of consulting wastewater engineers, Metcalf & Eddy, was brought in to submit proposals for dealing with the situation, and presented its report on July 1.[24]

Calco's response was to commence investigations of its waste streams, including the sludges that had accumulated in ditches, and to seek out ways of minimizing the impact of the effluent. The ditches were probably overextended and clogged with solid and liquid waste.

Moreover, waste from manufacture of coal-tar products was infiltrating into groundwater, contaminating one or two of the wells that supplied drinking and process water to the site. In November 1931, representatives from the NJDH turned up to take samples of liquid and sediment, typical of the waste directed to the Raritan River, from the ditches.

By 1933, the Raritan had deteriorated to such an extent that the NJDH directed Calco to construct a pipeline to carry its waste directly to the ocean. The company resisted this move strongly, doubtless because of the expense involved, and it came to nothing. However, three large waste lagoons were excavated in 1933 on Calco land west of the manufacturing area; around the same time efforts were made to organize the various ditches and sewers in order to differentiate types of wastes. This followed the introduction of vat-dye processes that employed aromatic solvents, and transfer of other processes from the recently acquired companies.

Rudolfs conducted the first comprehensive survey of industrial waste in New Jersey, and continued to undertake experiments on effluent, including that from the Calco factory, at the New Jersey Agricultural Experimental Station. The general problem of the impact of industrial waste on streams in the expanding residential region underscored his 1936 paper on "Stream Pollution in New Jersey: Importance of Industrial Waste." This described the results of a survey of 1,792 industries in northern New Jersey:

The problem of stream pollution in New Jersey is intensified by the density of population and industrial development. Fully two-thirds of the population resides in the northern part of the state, where manufacturing is of primary importance and greatly diversified. Textile dyeing and finishing, chemical, silk manufacturing, tanning, and steel plants and power laundries are among those producing large quantities of waste. Some of the waste is highly putrescible, some is poisonous, and some contains large quantities of suspended solids capable of settling in streams ... The water consumption of the industries from which samples were collected amounted to 54,600,000 gallons daily; the liquid wastes discharged amounted to 43,651,000 gallons per day. Rather complete analyses were made, consisting of different types of suspended solids, sludge volume, oxygen consumed, acidity, alkalinity, chlorides, pH, etc.[25]

Rudolfs and industrial-waste treatment specialist Dr. Hovhaness Heukelekian jointly undertook further investigations into pollution of the Raritan, into BOD, and dissolved oxygen (DO) content (a measure of the percentage of saturation). With others, they prepared critical reviews of literature on sewage and waste treatment, published in *Sewage Works Journal*. In the 1950s, Heukelekian, then a leading expert on biological oxidation of industrial wastewater, pointed out that it was "recognized that, for certain industrial wastes, biological treatment is neither feasible nor advisable ... commonly, industrial wastes contain a mixture of inorganic and organic compounds, either of which may have a biological inhibitive effect. The problems of tolerance levels and biological adaptations, synergistics and antagonistic effects of combinations of these compounds, becomes of paramount importance."[26] For domestic sewage, the overall picture was clearer, even if the mechanism of biological action was not.[27]

Calco was not the only manufacturer of aromatic chemicals in Somerset County to receive complaints concerning polluted surface waters. In 1935, the Board of Health of the Township of Bridgewater discussed the impact of waste discharged from the "Somerset Analine [*sic*] Wks.," near Pluckemin (today part of Bedminster) on the stream known as Chambers Brook, and the matter was referred to its counsel.[28] Interestingly, this was stated to be in violation of the New Jersey "Potable Water Act" of March 17, 1899, and its amendments.[29]

In August 1937, according to Victor King and colleagues, Calco and the NJDH built and operated for several weeks a weir and recording gauge to measure the flow of Calco wastes. This indicated that "a momentary maximum flow of 10,000 gpm [gallons per minute] of plant waste could be expected in midsummer." The NJDH, "aided by Calco at points adjacent to its plant, made a study of the pollution in the Raritan."[30] It was readily apparent that the flow of the Raritan River was barely sufficient to provide an adequate level of dilution for effluent entering the river, particularly during the summer months, when extensive periods of drought were common. Calco, however, claimed that through its system of lagoons and drains the main difficulties of color and suspended solids had been overcome. The NJDH thought otherwise, and in December brought pressure on Calco, ordering it in no uncertain terms to clean up its act, with particular reference to acidity and the oxygen-consuming waste that depleted the river's supply.

> The case under immediate consideration is that of Calco Chemical Company which discharges into the Raritan River ... an effluent which, among other things, has a high affinity for oxygen and which badly discolors the river waters for several miles ... it was stated on behalf of the Calco Chemical Company by its representative that the company had been studying the problem for some time in an effort to improve the quality of its industrial waste and has succeeded to such an extent that with respect to discoloration only minute particles of dye matter were discharged ... [A] report of investigation subsequently made [shows] that discoloration of the river water by the effluent of this company grossly exceeds this standard ... Following the discussion of the report with relation to the discharge of polluting material from the premises of the Calco Chemical Company, motion was made ... that the company be advised that at the next meeting of the Department of Health of the State of New Jersey a resolution and notice will be submitted for consideration in which ... it will be set forth that as minimum requirements the polluting material including domestic sewage must be subjected to a method of treatment which will

guarantee to produce results in the effluent as discharged into the Raritan River as follows: 1A. All free acids shall be neutralized; 1B. The color shall be such that it will cause no increase in color in the Raritan River ... for not more than 1,000 feet below the point of discharge; 1C. The oxygen absorbing properties of the treated waste shall not reduce the dissolved oxygen content of the Raritan River by more than four parts per million after intimate mixture is assured for not more than 1,000 feet below the point of discharge. 2. That the final effluent be discharged across the river through multiple outlets or their equivalents.[31]

According to the NJDH, Calco's response was that the best course of action would be to wait until projected municipal systems for treatment of domestic waste had been installed and only then determine the extent to which the Raritan could handle the factory's waste. This, Calco argued, would establish the type and level of pretreatment required prior to discharge. The proposal was immediately rejected by the NJDH, which in January 1938 placed Calco among the worst polluters of the Raritan River.

The Attorney General states that the Calco Company takes more than 12 million gallons of water a day from the river and returns it in highly polluted condition ... the attitude of the Calco Chemical Company is that action now is premature, that it should be delayed until the municipal plants are constructed in order to then determine what the condition of the river is and learn how much industrial pollution the river can stand ... That is the Cyanamid response. It totally misses the point of protection of our resources; nobody is entitled to put its dirty waste in our rivers ... The company said in effect that its sanitary wastes could be treated quite easily (although no steps were taken to do so) but that the company would prefer to put it all together with industrial waste and solve the problem together much later.[32]

To strengthen its case against Calco, the NJDH engineer was instructed to draw up a report on the impact of the factory's waste on the river. On March 8, the department's minutes recorded that from "inspections made by the Department representatives of industrial wastes, domestic sewage and other polluting matter from the premises of the Calco Chemical Co., and through inspections of Cuckold's Brook, [and] the Raritan River," it was determined that the discharged wastes "'are high in free acidity and color and have a high oxygen demand' and that these wastes are polluting the Raritan River by reducing the alkalinity of the waters, by discoloring the River, depleting it of its oxygen contained in the River, and therefore 'producing conditions that render the ... Raritan River unfit to sustain fish life and for use for recreational purposes.' Additionally, these wastes result in obnoxious odors and impair the sewage treatment works installed by certain municipalities." The conclusion was that Calco was violating the provisions of Title 58, Chapter 12, Section 3 of the Revised Statutes of New Jersey since the department had not allowed Calco to "permit any sewage or other polluting matter to flow into the Raritan River from the said sewers, drains and sewage systems under its control."[33]

Once more, and as in the previous December, Calco was "ordered that its industrial waste, domestic sewage and other polluting matter" should at a minimum be subjected to a method of treatment that would render it neutral and remove color.[34] No oil or grease that might make the Raritan "objectionable to the sight" would be allowed, and the oxygen demand of the wastes had to be reduced. Further, the NJDH ordered Calco to "cease discharging improperly, inadequately and insufficiently treated industrial wastes, domestic sewage and other polluting matter prior to July 1, 1938."

Calco's secretary, Colonel William S. Weeks, responded on behalf of the company that "industrial pollution is difficult to solve and would require more time" if the department's minimum requirements were to be met. He pointed out that Calco had already started work on effluent-treatment studies and requested that the NJDH give Calco until November 1938 to develop experimental plant, "which they are now constructing." Certainly it would not be possible to solve the problem within three months, "although they expect to have a pilot plant erected before that time." According to Weeks, Calco, "will use every effort, to solve this problem, at least in theory by November 1, 1938."[35]

Experiments on neutralization of Calco's acidic liquid waste were carried out with byproduct lime from Commercial Acetylene Co. of Lincoln, and carbonate waste in lime water from Johns-Manville, just upstream of the Bound Brook factory. The latter source was chosen because it was more economical, in part due to the proximity to Calco's proposed treatment plant, an area to the west of the main factory, thus minimizing the length of the slurry supply pipe.

Primary Treatment

Calco's investigations, including analysis for characteristics such as pH, BOD, and suspended-solids concentration, took longer than expected.[36] Finally, in April 1939, after some $20,000 had been spent on pilot-plant studies, plans for a full-scale waste-treatment plant costing $325,000, to treat 900 liquid wastes from 600 different processes, were approved by the NJDH.[37] An effluent satisfactory to the department required prior neutralization of acid, "and discharge shall not reduce the dissolved oxygen" downstream beyond 1,000 ft. from the point of discharge "below an average of 50 percent saturation." The amount of dissolved oxygen present in the river was to be measured by the company six times each day, while oil and grease on the surface of the river should not "produce sludge banks in the bed of the said river."[38]

The Calco liquid waste-treatment plant became operational in November 1940 and, it was claimed, "15,000,000 gallons a day of organic and dry color waste are treated before discharge as a clear, harmless liquid to the Raritan River." Liquid wastes from manufacturing buildings were transferred by pipes and ditches to a collection basin to the south of the main manufacturing area (basin number 25, according to a later numbering system, introduced here as an aid to identification), and then pumped to a large equalization basin (number 6, also referred to as lagoon, or impoundment). After retention for one day, the liquid was neutralized in a Dorrco neutralization unit designed and supplied by the Dorr engineering company.[39] The liquid was then passed to a settling basin (number 7) capable of holding 55–60 million gallons. Here, over three days, additional equalization of colors and other materials took place, as did "further reactions." Suspended material was removed, and the effluent stream was then directed via Cuckold's Brook into the Raritan River.[40]

A diffusion dam as "suggested originally by the New Jersey State Department of Health" was installed across the Raritan River "to diffuse the effluent almost immediately into the whole river ... The diffusion dam is so constructed that it draws in air with the effluent. This is very effective in putting dissolved oxygen in the river, especially during low water levels which occur in late summer." The aeration, however, created a foam, and to remove this a screen was installed, "made by attaching water-proof curtains on the downstream side of a pontoon bridge which is stretched across the river about 75 ft. below the diffusion dam."[41] The diffusion dam acquired the name Calco Dam, a designation which is still in use.

Since water downstream of the factory was not required for potable purposes, Calco considered its waste-treatment facility adequate.

> Water for drinking purposes is pumped from the river by several municipalities above the Calco inlet. However, below the entry point of the Calco waste, there is no water which is used as a potable supply pumped from the river. As the Raritan River and Bay are expected to be used primarily for recreational purposes, shellfish culture or the development of fish life, these classifications are the factors determining the degree of treatment required on the part of the industries and municipalities along the Raritan and its tributary streams.[42]

The *Bound Brook Chronicle*, in announcing that "Calco Shows the Way in Anti-Pollution Work," no doubt anticipated that the appearance of the Raritan River was about to be transformed.[43]

In the early 1940s, the Bound Brook manufacturing area covered around 100 acres, and consisted of 75 buildings where the wide variety of batch operations were carried out. The Calco Chemical Division employed about 4,500–5,000 people, engaged in the manufacture of dyestuffs, intermediates, rubber chemicals, pharmaceuticals, and mineral acids (sulfuric, hydrochloric, nitric), as well as in distillation of coal tar. Some operations were changed frequently, according to demand, with the result that the compositions of waste mixtures also changed. The diversity arose in part from the fact that "36 companies have amalgamated with Calco, and their plants have been moved to Bound Brook." Careful planning in handling the variety of wastes was required:

> In each case, before moving them, [Calco] technical men were sent to these

places for extended periods of time ... to prepare plans and process improvements necessary to eliminate as much as possible their effluent and odor nuisances. At Bound Brook the processes were arranged so that those of a similar character and with similar effluents were to be operated in the same or adjacent buildings. This early decision to group [together] similar products, and the system of connecting enclosed sewers, have facilitated the study and the supervision of the disposal of the effluents. In some cases the grouping of similar products has made possible a small recovery from the wastes which would not have been profitable if the similar products had been manufactured in scattered parts of the plant ... The present centralized system of water treatment was started early in 1930, prior to which treatments were located at different places scattered through the plant.[44]

Quite apart from tackling river pollution, there were numerous complaints from neighbors about the odors emanating from the plant that had to be dealt with. On July 15, 1941, the *Bound Brook Chronicle* reported that Colonel Weeks had pledged before the NJDH that American Cyanamid would make every effort to eliminate both water pollution and industrial odors. Measurement of atmospheric pollution at Bound Brook during 1939–49 was described by King and R. J. Jenny, the Calco safety engineer:

For some time a study was made of atmospheric pollution in our plant and in the surrounding neighborhood by means of a specially constructed traveling laboratory. This mobile laboratory was a station wagon in which was compactly assembled 80-odd pieces of analytical apparatus. It operated for many months, 24 hr. a day within a ten mile radius of the plant, studying all types of air contaminants which might or might not emanate from Calco. Much valuable experience and data were obtained. However, it is difficult to surpass the ability of the human nose by any apparatus yet devised.[45]

During 1942, when the wartime emergency situation created shortages of raw materials, Henry Spencer, the Calco waste-treatment engineer, asked chemists to determine if wastes contained recoverable and reusable material. Willem Rudolfs examined the quality of water available from the Raritan for greater chemical process use, including ice production, cooling, and steam supply. In *Chemical and Engineering News* during 1943, King and colleagues described the water intake as: "Clean, colorless, neutral water, containing minimum hardness, iron, silica, alumina, copper, and chlorine." As a patriotic aid to firms working under the pressures of wartime, the "[c]areful control and diversified treatment of water employed at the plant of the Calco Division of American Cyanamid is described."[46] Treatment-plant operations for the intake included coagulation, settling, filtration, softening, and chlorination. Now working at full capacity, the Bound Brook facility took 20 million gallons daily from the Raritan River, and more in summer according to the needs for cooling water. Water employed in cooling required only screening, and represented most of the intake. The Raritan water was generally neutral. However, upstream discharge of alkaline wastewater from the Johns-Manville works raised the pH, depending on dilution at high or low flows, and increased hardness.

Though "abatement of pollution became sublimated to the war effort during the 1940s," NJDH officials continued to undertake regular checks on the Calco well water. The threat to groundwater was ever-present. During the severe drought of 1944 the wells were investigated by another Calco consultant, Baltimore-based Sheppard T. Powell, chemical engineer, former lecturer at Johns Hopkins University (1929–33), and advisor to the National Resources Committee on Water Pollution. He was also consultant to the Manufacturing Chemists' Association, whose Water Pollution Committee was chaired by Walter S. Landis, vice president of American Cyanamid.[47] Powell specialized in industrial and sanitary water treatment, as well as in boiler feed and corrosion, the two areas where he was advisor to Bound Brook. The extensive use of consultants and consultancy firms, and not just in waste treatment, was, incidentally, a peculiarly American feature of industry, with few parallels in Europe. In this instance, Powell was instructed by Calco's Water Committee to investigate both river and well waters.

Powell made a thorough examination of the fifteen wells at Bound Brook, of which several were located in or close to the manufacturing area. Analyses carried out by the NJDH in June 1944 showed that water in one well was not safe for drinking, while three other wells had objectionable odors. Those wells contaminated by organic material and other wastes were taken out of service. The odors, particularly of nitrobenzene, were, as Erwin Klingsberg remembers from the late 1940s, apparent even in air-conditioning equipment that relied on well water. The extent of contamination was particularly noticeable during the drought of 1944, more so than during a drought experienced in 1941. New wells, with deeper casing, were driven, including on the company's Hill Property, at some distance north of the manufacturing area.

Calco's daily consumption of river water in the summer months sometimes exceeded half the total flow of the Raritan (which at the factory was made up of flow from the Raritan and Millstone Rivers, in the proportion of two to one, respectively). Data obtained from U.S. Geological Survey publications showed that between 1922 and 1940 there were some periods during which the daily flow of water did not reach 40 million gallons; it sometimes fell to 20 million gallons. Calco was planning a consumption of 30 million gallons a day of water to meet future requirements. Powell advised the Calco Water Committee that this could only be met by conservation measures. The river was also a source of supply for the Elizabethtown Water Company Consolidated, that since 1929 operated a large waterworks just upstream of the Calco Dam, and drew its supply from the Raritan and Millstone Rivers, and the Delaware and Raritan Canal.

In 1947, Powell presented a paper on "Creation and Correction of Industrial Wastes" before the Industrial Waste Symposium at the 111th meeting of the American Chemical Society, Atlantic City, New Jersey. This undoubtedly drew on his recent Calco experience.

Industry discharges wastes to streams that cover a wide range of organic and inorganic materials. These wastes may impart objectionable color, odor, or taste to receiving waters. They may have constituents that are toxic to aquatic or terrestial life, or are corrosive to hydraulic structures and equipment. They frequently contain substances with chemical or biochemical oxygen demands that tend to deplete the dissolved oxygen content of waters, which is essential for the preservation of cleanliness and proper biological balance. They may degrade the appearance of bodies of water and their shore lines, and may sometimes be the source of water-borne diseases that affect the health of bordering communities ... In some instances enforcing agencies have compelled industrial plants to carry out hasty decisions by setting deadlines for the construction and initial operation of treatment facilities. The complexities of the problems in many of these cases have not been adequately resolved, and results have been unsatisfactory to the enforcing agency and disappointing to the industry concerned. Continuing a policy along these lines may lead to serious financial losses without effecting the desired results. It is not intended to build a defense for, or attempt to justify, continued stream pollution by industry. However, it is believed that the law-enforcing body should temper its requirement to meet the situation, co-operate with industry, and guide corrective measures to avoid the installation of costly treatment works which, in the end, fail to solve the problem.[48]

Powell's central point, however, was that technical studies on the means for combating pollution by the chemical industry needed to be raised to the same status and level of sophistication as the development of manufacturing processes: "Industry should also assume its full share of such a program and provide the necessary technical skill, financial resources, and managerial guidance to provide corrective measures and constructive research. Such a program should be pursued with the same active interest shown in the manufacture of basic products. This procedure will avoid makeshift waste treatment processes and will prove to be economical."[49]

At a more mundane level, King and colleagues promoted the idea, as had the European dye industry around 1900 and American industrialists after World War II, that some of the dissolved oxygen content of rivers be sacrificed to the needs of industry. The Bound Brook proposal was discussed, and endorsed, at a meeting of waste-treatment specialists: "The data that Dr. King and his staff have presented lend support to the thesis that the Raritan River has sufficient resources of dissolved oxygen and alkalinity to provide a modest supplementary treatment for the Calco effluent."[50]

Calco was convinced that its treatment plant represented state of the art in the handling and processing of industrial waste. For the time, that was probably the case. In 1947, King demonstrated what was described as "the model industrial effluent plant" to a party from the Manufacturing Chemists' Association, headed by its president, Dr. R. W. Hess, director of research at the National Aniline Division of Allied Chemical & Dye Corporation.[51]

In March 1947, Rudolfs submitted a report on experiments with batches of waste from processes scheduled to be transferred to

Calco's section at the new Willow Island facility, and on the characteristics of sludges produced and stored over an extended period at Bound Brook. He paid particular attention to the tendancy of sludge to form a refractory material that, in his opinion, could be consolidated and safely stored without affecting the surrounding environment, particularly the atmosphere.[52]

Another American Cyanamid waste consultant during the late 1940s was Floyd William Mohlman, the first editor of *Sewage Works Journal* (1928–43) and director of the laboratories of the Chicago Sanitary District (later Metropolitan Sanitary District of Greater Chicago).[53] Mohlman undertook extensive studies into the modification of the BOD test, and, referring to land at the west of the Bound Brook factory, he observed that Calco "has an enormous area for mixing varicolored wastes and discharging an effluent of fairly uniform brown color ... However, residual B.O.D. is still a problem."[54]

While Calco was generally judged to be a major polluter of the Raritan River, there were also considerable difficulties created elsewhere in the Raritan Valley, including through the inaction of, and lack of coordination between, municipal authorities.

> State Control–The State of New Jersey has been trying to clean up its Raritan River for a long time. As far back as 1909, the State Board of Health served a cease-pollution order on the largest city in the valley, but it was not until 27 years later that a local treatment plant was built. It proved to be inadequate in only a few years ... Little else was done to treat the wastes of towns and factories until the 1940s. Then the state health officials, spurred by public demand, went to the courts for action ... The towns and a few industries built local treatment plants. These soon could not handle the volume of wastes. Continuous growth of population, and industrial expansion in the area, made the treatment plants inadequate.[55]

In 1951, on the occasion of the American Chemical Society's seventy-fifth anniversary, Mohlman summarized current perspectives on and approaches to industrial wastes. Previously industry had often claimed that domestic waste, by virtue of its sheer volume, represented a greater problem than industrial releases. Mohlman commented on how they now stood in relation to each other:

The waste disposal problem has become of paramount concern to industrial chemists. The importance of treating wastes from industry is recognized as being almost equal to the importance of sewage treatment, if our streams and lakes are to be maintained in decent condition. Industrial chemists are developing such processes as neutralization of acids, precipitation of solids, screening of food products wastes, and biological treatment of liquids, in efforts to eliminate the undesirable qualities of industrial wastes. Notable examples are the plants of the Dow Chemical Co., Calco Chemical Division of American Cyanamid Co., Celanese Corp., American Viscose Corp., Upjohn Co., and Lederle Laboratories ... Industry's acceptance of its responsibility for proper waste disposal has developed largely during the past 20 years.[56]

By this time, there was considerable awareness of the problems of groundwater pollution caused by industrial wastes in the United States.[57] Two cases of releases of aromatic chemicals received extensive publicity, both taking place in 1945, at Alma, Michigan, and Montebello, California.[58] There were a number of responses to contaminated waters, particularly where phenols and hydrocarbons were involved, for which strict regulations controlled releases.[59] From January 1946 to September 1947, *Petroleum Processing* (previously *National Petroleum News. Technical Section*) ran a series of twenty articles by Wilson Bregy Hart of Atlantic Refining Co. dealing with "Waste Disposal." In May 1947, *Industrial and Engineering Chemistry* devoted an issue to "Industrial Wastes." This included an article by two American Cyanamid (Lederle Laboratories) scientists who drew attention to the fact that it was no longer acceptable to dispose of waste by placing it in holes in the ground (which of course included unlined lagoons and ditches): "When waste consisted of a few pails of solid material, a hole could be dug in which to bury it, and nature did the rest ... but when there were created tons of solids and thousands of gallons of liquids, which might be obnoxious or even dangerous, the problem assumed quite a different aspect."[60]

General concern over water quality in the United States led to enactment on June 30, 1948, of Public Law Act 845 (62 Stat. 1158), referred to as the Federal Water Pollution Control Act. The surgeon general was the responsible executive, and the Public Health Service was directed to prepare, or adopt, comprehensive programs for resolving water-pollution problems in cooperation with states and

Aerial view of Bound Brook waste-treatment area showing basins, or lagoons, and Cuckold's Brook, looking toward the southwest, around 1950. Equalization basin no. 6 is to the left. To its right is the settling basin, no. 7. The Dorrco neutralization unit is between basins 6 and 7. In the distance, beyond the Raritan River, is the Johns-Manville facility. (Fairchild Aerial Surveys/Edelstein Library.)

interstate agencies, municipalities, and industries. This was the first time that legislation in the United States moved "strongly in the direction and control of abatement of pollution."[61] From then, if the states did not act, the attorney general, at the request of the federal security administrator, had the power to initiate legal proceedings in order to bring about pollution abatement.

While at Bound Brook some treatment at source was carried out, particularly in connection with recovery of valuable solvents such as alcohols, pyridine, and aniline, considerable amounts of nitrobenzene and various other refractory contaminants were present in wastewater, and some passed unchanged through the treatment system into the Raritan River.[62] The various difficulties of controlling releases of aromatic chemicals, and toxic metals, including arsenic and mercury, were shared with other manufacturers of dyes, including in Europe. Many firms were coming under pressure from municipal engineers, health authorities, and river inspectors. Some factories took measurements, and did little else. This was the recommendation of Floyd Mohlman to American Cyanamid, as recorded in a meeting with CIBA at Basel in 1951. His advice was to keep the authorities at bay by installing measuring instruments and generating a mass of data with which to impress on inspectors the fact that something was, apparently, being done about the waste.[63]

Grassroots movements of concerned citizens were also on the rise. In 1949, following passage of the water act, two thousand people joined the Restore the Raritan Society in Middlesex County, with the objective of bringing public pressure on municipal, county, and state officials to clean up the river. Calco responded by claiming that its liquid effluent was harmless.[64]

Mohlman's suggestion to CIBA may have been effective when the wide, deep, and fast-flowing River Rhine at Basel was used as the waste sink, but it was not the case with the much smaller Raritan River. In December 1946, while describing his recent trip to Germany, King had alluded to the inadequacies of the Raritan when considering the massive thousand-fold dilution available to the Bayer Leverkusen works, also situated alongside the Rhine.

Certainly the NJDH did not remain quiet. On July 16, 1952, Dr. Daniel Bergsma, its commissioner of health, wrote to Calco's Colonel Weeks regarding "violations" arising from releases of liquid waste. The NJDH, Bergsma explained, "has found and determined through an inspection made by its representatives on February 14, 1952 that an improperly, insufficiently and inadequately, treated industrial waste effluent was being discharged into the water of the Raritan River."[65]

On October 15, 1952, following an NJDH order for rapid reduction of pollution, Cyanamid filed a civil action complaint against the NJDH, stating that it would be "physically impossible" to comply. The outcome, a stipulation of extension of time (October 31), included agreement to submit quarterly reports. The June 18, 1953, Quarterly Report No. 3 was highly optimistic. "The program preventing discoloration of the Raritan River is well on schedule and the discoloration ... is now being steadily reduced. We expect to have this program completed during the next quarter so that at the beginning of the fourth quarter of 1953 visible discoloration of the Raritan River will be eliminated in so far as our effluent is concerned." This was in part supported by new initiatives under way at Bound Brook.

Secondary Treatment

Calco was certainly aware that more thorough treatment of liquid waste was required. In September 1953, for example, the Technical Committee of Department E was advised "that the ratio of river volume to Calco effluent was 3:1 during September. The color of the river during weekends is a faint brown which increases to a yellow at the end of the week."[66] The corporation had earlier commissioned studies into biological, or secondary, treatment methods based on the action of microorganisms in the presence of oxygen on waste. In 1949, preliminary studies on trickling-filter biodegradation, involving a stationary biological bed, as already employed at Lederle, were conducted for Calco at the Lawrence Experimental Station in Massachusetts.[67]

The work for Bound Brook was probably carried out under the supervision of Dr. Rolf Eliassen, former sanitary engineer at Dorr Co. (1936–39) and from 1940 consulting engineer (as Rolf Eliassen Associates), and associate professor at New York University. In 1949 he joined MIT's Department of Civil and Sanitary Engineering (later he moved to the Department of Civil Engineering at Stanford University). After small-scale experiments with trickling filters in glass and stainless steel apparatus gave promising results, a small pilot plant, with a two-foot diameter filter, was set up at Bound Brook. This was followed with a larger pilot-plant unit that began operating in late August 1953, a year in which, incidentally, there was a further severe drought. This work was supervised by Calco's consultant sanitary engineer, L. L. Hedgepeth. He was associate editor of *Water and Sewage Works*, which in 1954 featured a review of progress in four papers originally presented by Bound Brook and Lederle scientists at the 1954 Southern Industrial Wastes Conference in Houston, Texas.[68] Alfred B. Cherry, a sanitary engineer who joined Bound Brook in 1951, was placed in charge of pilot-plant operation.

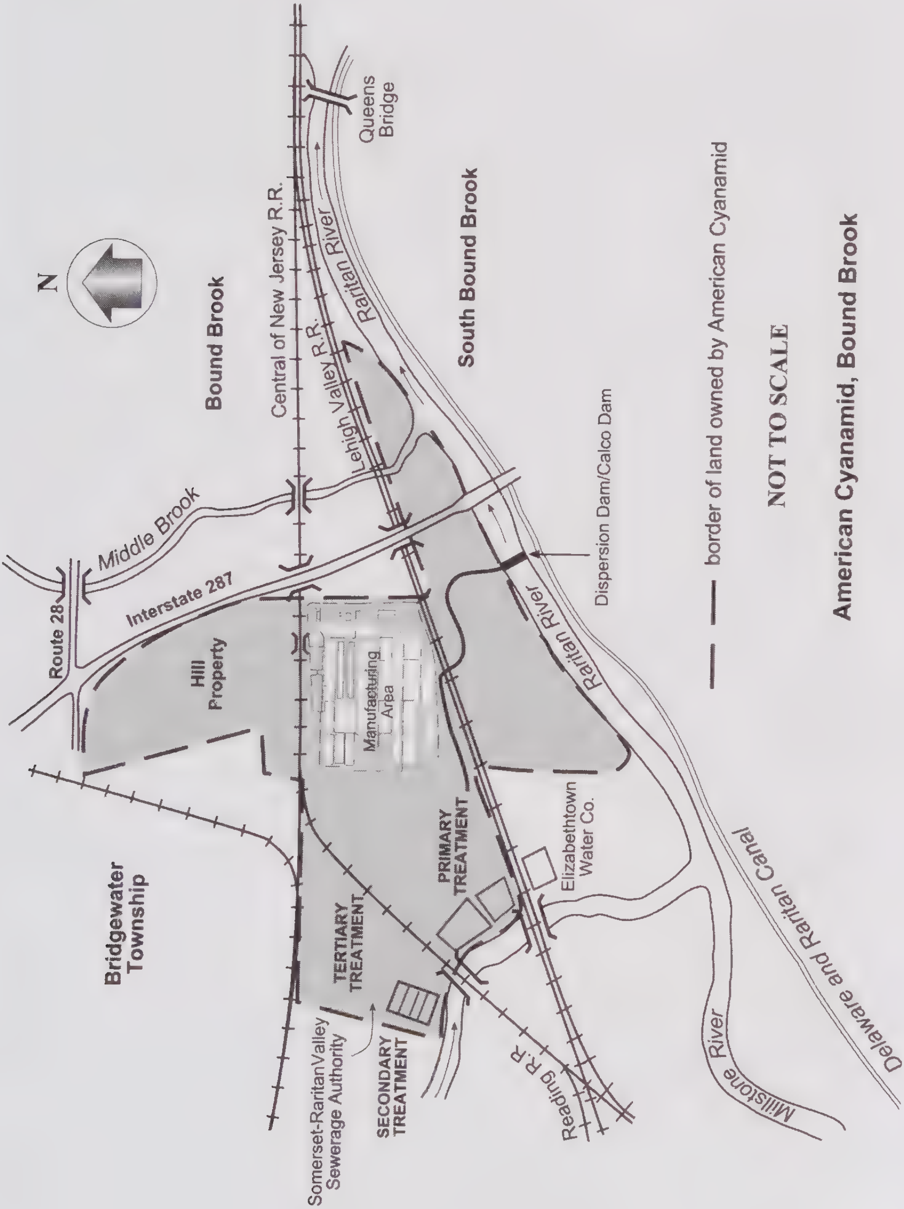
Changes in the organization of local municipal sewerage authorities encouraged greater collaboration in waste treatment. In 1948 the downstream Middlesex County Planning Board proposed to reduce pollution of the Raritan River through organized collection of all wastes from the heavily populated and industrialized region. With this in mind, in July 1950 the Middlesex County Sewerage Authority (MCSA) was created by the Middlesex Board of Freeholders. The MCSA had powers to abate stream pollution within Middlesex County and treat wastes from municipalities outside of Middlesex, including those located upstream. It constructed a 27-mile intercepting sewer from Bound Brook southeast to Sayreville, in Middlesex County, where a waste-treatment plant was constructed nearby.

Municipalities and industries located upstream of the town of Bound Brook, including Calco, decided not to join the MCSA.[69] Instead, in August 1952, the Boroughs of Somerville and Raritan, the Township of Bridgewater, the American Cyanamid Company, the Johns-Manville Corporation, and others agreed to create separate treatment facilities. At the same time, the Somerset County Citizens Committee was formed to represent the interests of local residents. Sheppard Powell and consulting engineers Whitman, Requardt & Associates, also of Baltimore, submitted to Calco and local organizations a comprehensive engineering report in April 1953.[70] By 1956, it was anticipated, abatement of pollution of the Raritan River could be complete.

The consultants recommended location of Calco's biological treatment plant at the western extremity of the Bound Brook site, close to the works of the new Somerset-Raritan Valley Sewerage Authority (SRVSA), opened in 1957, in anticipation that the authority's waste, after primary treatment, would be accepted and treated by the American Cyanamid secondary plant. Working together, they could reduce intake from, and releases to, the river. Bound Brook and the SRVSA came to an arrangement, summarized in *Chemical Engineering*:

> The main plant of American Cyanamid Co.'s Calco Chemical Division at Bound Brook, N.J., is a major participant in the Somerset-Raritan Sewerage Authority. Calco officials believe that there is not enough water in the Raritan River to allow for diversion of all municipal and industrial effluents along the heavily settled route. They footed most of the bill for an engineering study ... to provide a practical plan for pollution abatement in Somerset County, considering the water supply and pollution as inseperable problems. According to L. L. Hedgepeth, Calco staff consultant on pollution control and water supply, the drought this past summer proved conclusively that the river flow is insufficient to serve as a water supply for existing municipal and industrial waste treatment plants on the river.[71]

The biological waste-treatment studies involved contributions from microbiology, biochemistry, and engineering. Gathering quantitative data was often difficult, however, particularly BOD values. While the bioassay method measured the overall toxic effect in a river, the situation was complicated in the case of a facility such as Bound Brook, where batch-production processes were highly diverse and frequently changed. This was especially true of Department E effluent. In March 1954, George W. Hedden reported to the department's Technical Committee "that an agreement has been reached at Bound Brook that the BOD test is valueless in testing chemical effluents ... COD value (Chemical Oxygen Demand) is being determined instead. What we had been planning to do is now being done on a plant wide basis under a Central Effluent Committee." The Central Effluent Committee decided to discontinue BOD sampling and testing of all Department E mother liquors known to have high BOD contents.[72] For removal of color from Department E effluents, chemical methods, mainly reduction with iron and acid, were used, though not always with great success. Tests were undertaken in 1953 with sodium hydrosulfite, and in May 1954 the Chemical Engineering and Development Departments were brought in to tackle the difficulties encountered with "Basic Brown" effluents.[73]


American Cyanamid, Bound Brook
NOT TO SCALE
border of land owned by American Cyanamid
N
Bound Brook
South Bound Brook
Bridgewater Township
Route 28
Middle Brook
Interstate 287
Central of New Jersey R.R.
Lehigh Valley R.R.
Raritan River
Queens Bridge
Hill Property
Manufacturing Area
Dispersion Dam/Calco Dam
PRIMARY TREATMENT
TERTIARY TREATMENT
SECONDARY TREATMENT
Somerset-Raritan Valley Sewerage Authority
Elizabethtown Water Co.
Reading R.R.
Millstone River
Delaware and Raritan Canal

In November 1954, the new Organic Chemicals Division (OCD) general manager, V. E. Atkins, instructed consultant Sheppard Powell to conduct a more thorough investigation of biological treatment of liquid effluent. Powell favored trickling filters, following removal of waste that poisoned the microorganisms. In 1955, James Christian Lamb III, a former student of Eliassen at MIT, where in 1953 he received the Sc.D. in sanitary engineering, was employed by American Cyanamid to develop biological treatment at Bound Brook. Lamb, who took over from Hedgepeth, worked closely with Powell and undertook a series of BOD measurements on various chemicals using acclimatized seeds. He also contacted other manufacturers, including Dow Chemical Company at Midland, Michigan, that employed mainly the trickling-filter system, though they had some activated-sludge units, and Merck, that had installed biological-treatment facilities. Further studies at Bound Brook demonstrated that biological treatment with activated sludge was far better suited to breaking down the industrial waste than was the older trickling-filter process, based far more on rough-and-ready empiricism. Activated sludge treatment became the method of choice.[74]

The final process design of the Bound Brook biological waste-treatment plant was undertaken by Lamb, who confronted not only particularly high overall BOD loads but also the problem of refractory organics that poisoned the microorganisms. The beta-naphthol and pharmaceuticals facilities, in particular, were sources of large amounts of difficult waste. Despite considerable progress, the Bound Brook Quarterly Report no. 13 of January 19, 1956, took a cautious approach:

> During the latter part of the period, aeration tests previously mentioned were continued on a much larger scale and with equipment suitable for continuous treatment of plant wastes. The results are significant but must be continued for a longer period before drawing final conclusions on the efficacy of this method of treatment. Work has also been continued on the investigation of procedures to be followed in primary clarification of the wastes after neutralization of acidic components. Data have been gathered on settling rates, degree of compacting and concentration of solids and sludge residue. Research has been continued in many phases of our investigation of the treatment of plant wastes.

Meantime, the condition of the Raritan continued to arouse concern.[75]

The high BOD load, and variability in waste characteristics, were the main reasons why Bound Brook elected to build its own secondary plant rather than join a regional sewerage authority. On March 28, 1957, with due ceremony, ground was broken for a $4.5 million activated-sludge plant, to occupy 58 acres and handle 17 mgd of wastewater. The plant, designed to be operated by about 25 people, included an administration building, with laboratory and pilot-plant facilities, six reinforced-concrete aeration tanks, each 65 feet wide, 400 feet long, and 16 feet deep, and six final settling tanks, 80 feet in diameter and 10 feet deep, also made of reinforced concrete. The bottoms and walls of the aeration tanks were equipped with nozzle-type aeration diffusers, and the settling tanks with vacuum-type sludge collectors.

According to an American Cyanamid account: "In commenting on the significance of the event Robert S. Shaw, Assistant Director, Division of Environmental Sanitation, NJDH, said, 'I have never seen a better example of industry-community cooperation than has been exemplified in the way in which Cyanamid and the Somerset-Raritan Authority have worked together to solve the pollution problems in the upper Raritan. Today's ceremony is a tribute to their teamwork and far-sightedness.'"[76] Thereafter work proceeded rapidly, in accord with the planned schedule.[77]

The much-publicized dedication was held on June 4, 1958, when, in the presence of Richard R. Stout, acting governor of New Jersey; Dr. William H. Bowman, general manager, OCD; Col. J. M. Fasoli, manager of services, OCD; and other dignitaries and senior management, Kenneth H. Klipstein cut the symbolic ribbon. Commissioner of health Daniel Bergsma declared: "This event marks the culmination of many years of painstaking work by the engineers, scientists, and management of Cyanamid and the New Jersey State Department of Health. I am confident the plant will effect a major contribution to stream pollution abatement and control in New Jersey."[78]

The event was preceded one day earlier by an Air–Stream Pollution Control Seminar at Bound Brook, at which Bergsma gave the keynote address. The morning session, devoted to air pollution, was moderated by W. R. Bradley, chief, Industrial Hygiene, Bound Brook, while the afternoon session, concerned with steam-pollution control, was moderated by Heukelekian, then head of the Department of Water Sanitation, Rutgers University. Among the topics discussed were national and state stream-pollution control programs and toxicity studies in stream pollution. Lamb, in his paper "The Cyanamid Story at Bound Brook," described the development work leading up to the new installation.[79]

Alfred Cherry was mainly responsible for liquid-waste treatment at Bound Brook during 1957–64. In November 1959, he presented a paper on "Biological Treatment of a Complex Chemical Waste" to the Southwestern Regional Meeting of the American Chemical Society, held in Richmond, Virginia. Bound Brook liquid waste was described as "the color of light tea, having a pH of 1.4–2.0." After the pH was adjusted to 6.5, the liquid was transferred to the large 1940s settling basin. A pumping station, equipped with five pumps, delivered the process waters, sanitary sewage, and storm runoff into the biological-treatment plant, where the liquid was distributed among the six aeration tanks that supplied oxygen and maintained the particulate material in suspension. "Oxidation is accomplished by the introduction of air streams under about eight pounds per square inch pressure, produced by two large compressors, each having a capacity of 25,000 cu. ft./min. The organisms present in the activated sludge get their energy, grow and multiply by digesting the organic content of the effluent."[80]

In the settling tanks, sludge was removed and returned to the aeration tanks to supply organisms to treat the incoming wastes. The liquid was then chlorinated and discharged to Cuckold's Brook. A newly installed incinerator was used for disposal of excess sludge.[81] The liquid-effluent plant treated an average of 23 mgd, with a total BOD loading of about 55,000 lbs. per day. The pH of the wastewater was controlled to a value of 7 by the addition of lime prior to the biological treatment.

American Cyanamid adopted proposals made by Powell, and by Whitman, Requardt & Associates, in a January 1956 report to the SRVSA, that Bound Brook accept the authority's settled-sanitary sewage for secondary treatment.[82] In September 1957, arrangements were completed for a formal contract that made the new plant available for biological treatment of SRVSA effluent.[83] Over the next five years, "Cyanamid's facility gave secondary treatment to 5,388.6 million gallons of the Authority's sewage from Somerville, Raritan and Bridgewater."[84] In total, the biological-treatment plant processed 40 billion gallons of effluent. American Cyanamid personnel held posts on the SRVSA, including Anthony Santora, as long serving treasurer, since 1957, and James Dobson Jr., who served several terms as chairman in the 1960s.

The outcome of Cyanamid's efforts was that the NJDH consented to dismissal of the litigation commenced in 1952. The corporation was advised by Waldo R. McNutt, NJDH chief of legal affairs, that the "cooperation rendered this department by American Cyanamid Company has been of the highest caliber. I am happy to tell you that the department concurs in your request for dismissal. Permit me to express to you our appreciation of a job well done."[85]

Lamb, who also worked at other American Cyanamid sites, left the firm in 1958 to take up a post as associate professor of sanitary engineering at the University of North Carolina at Chapel Hill. He was retained by American Cyanamid as a consultant. In 1959, jointly with Powell, he published a paper on cooperation between Bound Brook and municipal authorities.[86]

Further Studies

Despite the introduction of secondary treatment, and the initial optimism and self-congratulation on all sides, NJDH inspections showed that the color of treated waste released to the Raritan continued to be unsatisfactory. The liquid discharged to the river had a tea-brown color that during times of low river flow was noticeable downstream from the facility. A June 1, 1960, memorandum from Harry H. Hughes, senior public health engineer, NJDH, noted that "final effluent carries considerable residual color." The reason for this was that microorganisms were unable to acclimate to many aromatic compounds, which in some cases also poisoned the microorganisms. This meant that certain dyes and intermediates and their oxidation products escaped into the river.

At the August 1961 conference dealing with pollution of the

Raritan River and Arthur Kill, American Cyanamid was listed as one of fourteen large firms discharging into the Raritan.[87] A year later, publication of Rachel Carson's *Silent Spring* generated unprecedented public awareness of the many environmental problems facing the United States, including pollution of waterways. The series of new environmental regulations instituted soon after impacted greatly on industrial concerns, particularly those, such as American Cyanamid Bound Brook, that discharged effluent into a relatively small receiving water. They also encouraged various invectives and highly charged campaigns against the chemical industry.

From around 1960, another unit of the NJDH, the Bureau of Fisheries, Division of Fish, Game and Shell Fisheries, became more actively involved in combating industrial pollution of the Raritan. In December 1962, A. Bruce Pyle, assistant chief of the bureau, reported that he had monitored the Raritan ever since the secondary-treatment plant began operating. "From inspecting and monitoring the Raritan River during those years 1957 through 1961, it was our determination that a major source of the pollution in the Raritan River was due to the discharge of the American Cyanamid Company in Bridgewater Township, N.J. … It became apparent that after negotiative efforts to correct the pollution problem, they were not meeting with success."[88] The continuing high BOD load of Bound Brook releases on the river was a major part of the pollution problem.

Cherry had to deal with the very high BOD level, as well as with variations in the level. Improved aeration was considered a likely solution to these difficulties. His successor as Bound Brook sanitary engineer in 1964 was James (Jim) R. Grube II, who worked closely on aeration and other aspects of waste treatment with Lamb as consultant. Progress was not rapid. On November 21, 1964, the acting mayor of New Brunswick, Mr. Horvath, prepared a statement concerning the Raritan that was clearly aimed at American Cyanamid: "[D]ue largely to industrial contamination near Bound Brook, the goal of a clean, usable river has not been realized … Bound Brook industrial waste has been rampant and almost unchecked."

On April 14, 1965, the NJDH's Robert Shaw, then assistant director, Water Pollution Control Program, Division of Clean Air and Water, dispatched new regulations concerning the Raritan to American Cyanamid's attorney at Wayne: "Enclosed for your information is a copy of regulations of this Department, filed with the secretary of state on March 22, 1965, entitled 'Classifications of Surface Waters of the Raritan River Basin Including Raritan Bay.'" Shaw also enclosed a copy of "Regulations Establishing Certain Classifications to the Assigned Waters of this State and Standards of Quality to be Maintained in Waters so Classified," filed with the secretary of state on August 10, 1964. Shaw pointed out that the

> latter-mentioned regulations establish definitions of surface water classifications and quality criteria for the various classifications ... A substantial part of the waters of the Raritan River do not conform to the established water quality criteria. The active cooperation and participation by all parties concerned is desirable in order to supplement a program to attain and maintain surface waters in the Raritan River basin having a quality conforming to the established water quality criteria. We solicit your support, cooperation and active participation in this much-needed program in the interests of all parties concerned.[89]

One day later, on April 15, the NJDH issued even more stringent regulations that were to come into force from February 1, 1966. These new regulations were connected to criteria laid down by the Interior Department's Federal Water Pollution Control Administration, pursuant to the 1965 Water Quality Act. States were required to specify criteria for potable water, aquatic standards, and recreational water, including threshold odor, maximum bacterial count, dissolved oxygen, dissolved solids, and pH.

These New Jersey regulations required that American Cyanamid's treated waste met the F–W–3 criteria, that is, water usable for recreational purposes, but not for public potable use. On February 18, 1966, the NJDH issued an order to American Cyanamid concerning its sanitary and industrial waste "discharged into the water of the main stream of the Raritan River between its confluence with the Millstone River and the Fieldville Dam," the latter located about three miles downstream of the Calco Dam. Since this release was judged to contribute considerably to the pollution load of the Raritan River, the company was ordered "on or before June 1, 1966, to alter, add to or improve its waste water treatment and disposal works ... in order that the waters receiving said effluent shall conform to the standards of quality established" by the NJDH.

Cyanamid's response, on May 16, was a document that dealt with its water consumption from the river, and the need for six years of work in order to meet the revised NJDH requirements. This was discussed eleven days later at a meeting with the NJDH. Commissioner Roscoe P. Kandle advised American Cyanamid:

> We regret to advise you that we are obliged to reject your presentation dated May 16, 1966 in response to our Order of February 18, 1966. We have given due consideration to your presentation and to the proceedings of the conference held in relation to the same in the offices of this Department on May 27, 1966. We note that your proposal to conform with the requirements of this Department is predicated upon the assumption that you will receive water of "adequate volume" in the Raritan River as it reaches the location of your plant at Bound Brook. Neither you nor we are in a position to assure such an "adequate volume" of water. We, therefore, cannot accept this as a premise for commitment to comply with our Order of February 18, 1966. We note that you contemplate approximately six years of time to accomplish the various projects outlined in your presentation. This time period is considered by us to be incompatible with the best interests of the Citizens of this State, particularly the citizens of the Raritan Valley downstream from the point of discharge, to find industrial waste effluent from your plant at Bound Brook. We would urge that you develop some means for reducing this time element at least fifty percent ... We recommend that you give reconsideration to your presentation of May 16, 1966.[90]

During 1965–66, the NJDH had conducted an extensive survey of the Raritan under the direction of Pyle. In August 1966, when William (Bill) B. Prescott was head of Bound Brook's Effluent Task Force, American Cyanamid carried out a separate survey in cooperation with the Raritan Valley Clean Water Association. Students at the Bound Brook MIT Practice School were assigned to the problem of highly colored effluents from buildings 43, 62, and 63. This was part of the "Effluent Quality Survey" that sampled and analyzed effluents from all manufacturing processes. In 1969, the results were used by the Effluent Technical Group when drawing up data to study an at-source control program.

Atmospheric Contamination, and Liquid Waste

Over the years, the need to improve working conditions and atmospheric quality at Bound Brook stimulated process changes and the installation of precipitators and scrubbers for removal of gaseous contaminants and dusts. Certain problems of olfactory releases had also been tackled. Thus in the Rubber Chemicals Department, benzothiazole (BT) present in exhaust from the dryers created a highly objectionable odor, that at first was removed by passing the dry exhaust through packed towers using sulfuric acid as the scrubbing medium. "Another exhaustive inquiry revealed the BT could be removed after the first step in the manufacturing process (autoclave reaction) by steam stripping of the autoclave melt. On this basis expenditure of $85,000 was made in 1951 on such equipment."[91] It was claimed that all of the BT was removed in this stripping operation.

From around 1963, the hygiene aspects of air-pollution control were directed by Russell S. Hunt, the plant industrial hygienist. One major disposal problem eliminated in the mid-1960s followed the introduction of the new catalytic aniline, or Catan, process. The 12,000 tons of spent iron generated annually in the original process presented massive storage and dust problems which were exacerbated by a degreasing step that released a mass of smoke. The new plant overcame these nuisances almost completely.

Other solid or tar-like wastes also contributed to atmospheric pollution. "In many cases ... it is necessary to dispose or impound these wastes on plant property. These areas are under constant surveillance and require regular chemical treatment or flooding with water to prevent the emission to the atmosphere of objectionable odors or dusts." Vapors containing acids at the plant were absorbed in scrubber towers. "Each year the plant manufactures many tons of sulfuric acid by the contact process ... A final absorber ... reduces the SO_2 content of the exit gases to about 5% of the standard contact plant and eliminates any air pollution from this source." Recovery of sulfuric acid created an acidic mist, caused when hot air was blown through the diluted acid to remove water. In 1941, a Cottrell precipitator was installed to catch this mist by electrical precipitation. Twenty years later the precipitator was replaced by a Venturi scrubber.[92] Plant odors included the nitrobenzene from air-conditioning equipment that used contaminated well water. Hunt's work on understanding these problems was assisted early in 1971 with the arrival of a Tracor 3 (electron capture detector) gas chromatograph for gas analysis.

When on January 9, 1967, the NJDH issued an amended order concerning the operation of Bound Brook's "waste water treatment and disposal works," atmospheric as well as water studies were demanded, as was upgrading of the biological-treatment plant. Moreover, a construction schedule for new waste-treatment facilities was required by the beginning of 1970.[93] On July 5, 1967, Bound Brook's plant manager, George W. Hedden, submitted a progress report to the NJDH's Roscoe P. Kandle. Hedden reported that pilot-plant studies on air dispersion had been completed in November 1966, and studies on liquid waste had been successful and established the efficacy of surface aerators in achieving substantially increased biological efficiency. Ten Yeoman's 75-horse power surface aerators, and ancillary equipment, were on order, with delivery expected by October 1, 1967. Large-scale trials in one of the three units of the existing activated-sludge plant were scheduled to commence during January 1968: "We continue to carry out laboratory and pilot plant studies dealing with the broad technology of the treatment of industrial and domestic wastes."

Apparently this was not enough to satisfy the NJDH. On July 24, 1967, Ernst R. Segesser, chief engineer, Water Pollution Control Program, Division of Clean Air and Water, NJDH, advised Richard J. Sullivan, director of the division:

> I have received Mr. Hedden's letter of July 5, 1967, which I assume comprises the comprehensive progress report required to be submitted to the Department at least semi annually. I do not consider this July 5 letter as being of sufficient detail to be considered as complying with Item 7 of the January 9, 1967, Amended Order. Item 2 requires that the plant studies be completed by March 1, 1967 and Item 5 requires the Company to initiate and continue practices of color removal. It would seem appropriate for us to request the results of the studies as required in Item 2 and also information as to what has been done in relation to Item 5. Incidentally, we have not replied to Mr. Hedden's letter.[94]

On August 11, Segesser requested "more details of certain studies required to be undertaken" according to the requirements of the January 1967 amended order.

A Public Hearing in New York, and a Conference

Federal interest in pollution of the Raritan was also aroused, and a public hearing was scheduled to take place in New York during June 1967. On learning of this, New Brunswick mayor Frederick Richardson wrote on June 2 to Stewart Udall, secretary of the interior, for further information, asking "(a) are these New York meetings open to the public, (b) will they cover the upper reaches of the Raritan River, where a good deal of the pollution originates, mostly in the vicinity of the American Cyanamid (Calco Co. Branch) area?" Richardson drew attention to the difficulties created by the fact that Bound Brook lay within Somerset County, and outside the control of the Middlesex County Sewerage Authority. Moreover, in his view, the NJDH had not acted in the best interest of the state's citizens, while much greater action was required from federal agencies.

> For thirty years or more the City of New Brunswick, especially during my encumbrance as Mayor, has been striving to get some relief from the Bound Brook situation that involves principally Calco. Although Middlesex County has had a sewerage Commission [Authority] in operation for many years, this Commission has been ineffective as to Bound Brook area, because the source of this pollution is Somerset County. The State Board of Health, which has the primary obligation, has been more than ineffective, and for thirty years, practically the same situation has continued. This pollution will certainly continue into the indefinite future so far as local and state enforcement is concerned unless the Federal Government acts to plug the main source of the river's pollution, namely, Calco Chemical at Bound Brook. Until this is done effectively by the Federal Government, all your other efforts in the [Raritan] Bay are likely to be seriously impaired.[95]

American Cyanamid was not represented at the June meeting in New York, as was noted at an October conference on the future use of the Raritan convened by the Federal Pollution Control Bureau at the request of state agencies. There was further criticism of American Cyanamid:

That the city of New Brunswick officially is interested in potable water is shown by Acting Mayor Horvath's statement of November 21, 1964 ["Goal Never Realized"] ... We hope there will be no further state or county laxity and indifference in the future, like there has been in the past, and although Federal legislation has not so far given private citizens the right to invoke the enforcement procedure prescribed under the State and Federal regulation ... nevertheless, this authorization will eventually be given the urgent necessity thereof ... Oyster beds can be re-established and protected, and the waters of this river restored to public use where it belongs. But to fully understand what this area has been deprived of, the history of pollution in this Valley and the inertia of the law enforcement must be rehearsed, because this condition can only be understood in the light of what has already happened over the last 30 years ... A recent Harris Survey has shown that the public rates ... local industry as the most negligent ... (attention is herewith called to the Raritan Valley industries that are overwhelmingly chemical, some [wastes] of which are untreatable, for example, Calco Chemical Co. (Branch of American Cyanamid Co. at Bound Brook), to which reference is made in the letter [from Mayor Richardson to Udall]).[96]

The conference proceedings also constituted a summary of the history of pollution of the Raritan over the previous four decades, including difficulties between authorities, the riparian or "prior appropriation" ("grandfather law") rights of American Cyanamid, and the demands of New Brunswick.

Many examples [of violations] exist and some have existed for 30 years (for example Calco Mfg. Co was notified as far back as 1937, and still are polluting the river in spite of all notices, complaints, orders and whatnot to the contrary). Further, it is noteworthy that none of these [polluters] appeared to explain their violations at the public hearing in N.Y.C. (June 1967), when they all well knew their violations would be publicly discussed. They were conspicuous by their absence ... If pollution is stopped at Bound Brook at Calco's, New Brunswick will be able to get potable water and with some filtration, use it as a source of potable water supply ... It is hopeful that this study now being made will recognize ... that polluting offenders upstream are violating these rights daily by their pollution, especially in and around Bound Brook, and this user [Calco] is an unreasonable one and should be stopped ... Lest it be thought New Brunswick has not tried and exhausted every remedy, let it be noted that 35 years ago the State Board of Health promised to abate factory pollution all along the Raritan River, upstream of New Brunswick, as well as downstream, as soon as the municipalities had completed their plants. Once these municipal plants were built, these written public pledges were ignored by the State Dept. of Health ... [New Brunswick] secured the promise of the State Board of Health that once the County Sewerage Commission was created, which was then being organized (1953), that if this County Sewerage Commission did not correct pollution of the River, the State Board would step in and do the job. This promise was never kept, although it became evident many years ago that the Middlesex County Sewerage Commission efforts were not successful. Today, the River is almost as bad as it was 35 or 40 years ago, and this condition is caused by the repeated failure on the part of the responsible agencies, the State Board of Health, and the Middlesex County Sewerage Commission ... Neither of the two bodies have made any appreciable impact on the pollution load of this River for the last 25 to 35 years, and our appeal to the Federal Government is the course of last resort. Most of the pollution is due to factory waste in and around Bound Brook and for some reasons, these factories seem to enjoy immunity to use the River as an open sewer. They seem to be above the law. The hub of most of the trouble is the State Water Dept.'s permission to Calco, to withdraw some 29 mgd from the River daily, under the so-called Grandfather's law. The Calco factory uses this water in its daily processes and then returns it, with waste from other adjoining nearby places [the Somerset-Raritan Valley plant], via its sanitation plant, back to the river, contaminated to a most serious degree ... Calco and that area refused either to build their own Sewerage Disposal System or to join the Middlesex County System, and have continued to refuse to date. So they created a sewerage impasse never since resolved.[97]

Yet another version of historical events, also highly critical of the state health authorities, accompanied an October 1967 report from Sayreville that recommended holding back expansion of its waste-treatment plant, slated to include secondary treatment, as demanded by the state, until such time as American Cyanamid's waste problems were overcome.

[No] further enlargement of the Sayreville plant should be undertaken until upstream pollution at Bound Brook is first so controlled and handled, that neither now or in the future, can the upstream pollution cause unsatisfactory plant operations at Sayreville. This has been the Sayreville plant's constant complaint now for over 10 years and it must be cured now before further treatment is contemplated. This further treatment is not designed to cure Calco's waste, which indeed is thought to be untreatable, and as long as untreatable waste comes into the stream, there is no use trying to cure pollution. This condition up at Bound Brook has existed for 35 years or more under claimed Grandfather rights, and even if ordered out of the River entirely, Calco will fight any attempt by anyone, County, State or Federal, to interfere or deprive them of their claimed rights to withdraw 29 mgd from the River and to use it in their factory and to return the used waste into the river stream ... The State Board [of Health], starting in 1930 with the municipal plants, failed to follow through with industry, so its efforts were of no avail despite all its promises and pledges ... it has now reached a point where the State Board of Health has forfeited public confidence ... all we can look forward to is a long court fight with Calco. With or without state help, Calco intends to continue its pollution as it has been doing for 35 years. Now the irony of this secondary treatment at Sayreville, aside from its inability to correct Bound Brook pollution, is that this secondary treatment is ordered by the same Board of Health that has let Calco pollute for all these years. If they have not corrected Calco in 35 years, we have no faith that they are the ones to now order us to spend 25 million dollars more on secondary treatment ... we want Federal grants to be protected against what we think is going to be largely a waste of public funds, unless Calco is made to conform to a workable pattern ... We want the door closed on further excuses and we want Bound Brook pollution stopped now ... The Middlesex Sewerage Authority, created in 1950 ... made a new start possible ... and there was great hopes entertained by the Authority of cleaning up.

The Authority has been requested to sue these polluters, like Calco, on the theory that downstream users have a right to a "reasonable user" of the water in the stream ... an editorial in the *Daily Homes News* of New Brunswick, N.J., Dec. 17, 1964 ... sums up the net results of what happened between 1953 and 1964: "Elson T. Killam Associates, hydraulic and sanitary engineers, are the city's consultants on water problems ... They report ... at Manville the river is 'relatively good,' then 'intermittently moderate to substantial' pollution to the Calco Dam and 'heavy pollution' below the dam."

In 1964 (Nov.), which is now less than 3 years ago, the City's water expert, engineer and consultant, Mr. Elson T. Killam, testified at water hearings in Trenton, as to the conditions he then found in the Raritan River above and below Bound Brook ... No fish life has been there for twenty-five years, not because of domestic pollution, because that was always present, even 25 years ago, but fish left when the factory wastes arrived—increasing chemicals eliminated the necessary oxygen, and all forms of aquatic life died. No bathing was possible and there were even reports of a suffocation of a boy, from chemicals, in a case where he accidentally fell overboard in the River, up near the Bound Brook [Calco] Dam, a few years ago. The bottom of this river, except where swept by the tide, is mostly ... an accumulation from chemical solvents. The river banks, especially where it extends into shoal water, are coated with a black chemical deposit, and even if the present chemical pollution were all to stop today, it would be years before all the deadly accumulation of chemicals at the bottom of the River and along its banks is gotten rid of. A drawdown of the lower level ... near New Brunswick, showed what the bottom of the river must look like in spots. It must be full of chemical solvents that have settled in the mud ... But where all control was lost was when chemical factories were allowed almost carte-blanche in their operations, and this we repeat must be controlled before further enlargement at the Middlesex down-river end is attempted. Less than 3 years ago, Mr. Killam found samples of dissolved oxygen to be below 50% saturation. Many instances showed 25%, and in some areas as low as 5%. At least 80% dissolved oxygen is minimal requirements to a healthy body of water. Less than 3 years ago, near the Bridge at Bound Brook, the B.O.D. was 35 parts per million (ppm), which is 3 times higher than what the effluent from a well-operated sanitation plant should show. At the same time, bacteria was in some cases 110,000 per 100 milliliters for samples, where it should not have, normally for a healthy stream, exceeded 70 per 100 milliliters. Color was very high running to 200 parts per million. Odor determinations were consistently objectionable, being characterized as chemical and musty. pH was widely variable, indicating a discharge of industrial waste. It varied from 6.1 to 8.8 ... Total solids below Bound Brook went as high as 1,100 or 1,200 parts per million ... [On October 9, 1966, a newspaper article stated] "Test results of water samples released this week by the Raritan Valley Clean Water Association [RVCWA] show an unusually high biochemical oxygen demand both in the effluent of the American Cyanamid Co. plant in Bound Brook and in the river water 150 yards below Cyanamid's outlet, according to the RVCWA ... Water samples taken above the Cyanamid plant indicated a satisfactory BOD level and bacteria count. The tests show that the river below Cyanamid does not meet present standards for color, odor and deleterious substances, according to the association, and that the primary cause is pollution added by Cyanamid. The association claims that although the state does not now require any minimum levels for bacterial count, BOD, and total solids, the test results show that these yardsticks of pollution are also excessive. The sanitary survey, made August 31 by the Middlesex County Sewerage Authority at the request of the RVCWA is part of the groups' continuing drive to have state authorities take action to clean up the Raritan River."

This article clearly shows the continuance of the conditions complained of at Bound Brook ... Bound Brook may be under a timetable, but in view of past experience, this timetable will not be met. The wastes of this area have not submitted to treatment for 30 years, despite the lavish expenditure of money, and there is no reason to think times have changed ... a timetable is meaningless, as we have found out, unless predicated on some over-all remedy of removing these wastes out of the river entirely. Assuming the wastes continue from upstream pollution, what good is secondary treatment at Sayreville? The river will stay the same as it now is until it reaches Sayreville, unless Calco becomes a participant ... Then again, there is no assurance that secondary treatment at Sayreville will be the answer. Some wastes, of which Calco's so far has been one, are simply untreatable ... Lest it might be thought that Calco will either adequately treat their wastes, according to a progress timetable, or be put out of the river, let me add that Calco claims rights, which with recourse to the courts, may carry as far as the U.S. Sup[reme] Court and entail 5–7–10 years delay. That Calco will do so is not an empty threat, under their so-called Grandfather rights. In this connection, do not let us lose sight of Calco's fight in 1933, against a pipe line solution. Their attention was then vigorously called to this necessity, and the fight was carried all the way to Governor [Alfred E.] Driscoll, but Calco resisted all pressure and insisted on the return of its wastes to the river, and as a result of this recalcitrant attitude, the ensuing trouble came about ... That Metcalf & Eddy are again the engineers who will design this secondary treatment, does not, in view of their previous failure, create any public confidence that they will be any more correct this time, than they were thirty years ago.[98]

In the face of growing criticism, American Cyanamid at the end of 1968 decided to enhance the efficiency of its secondary-treatment plant through further increases in the level of aeration. Jim Grube recommended supplying the secondary system with additional oxygen sufficient to treat at least 70,000 lbs. of BOD per day and, occasionally, even somewhat higher loadings. This could be achieved through installation of a further eighteen surface aerators to enhance the level of available oxygen. Grube's recommendation was approved and the aerators were installed during 1969–70.[99]

In 1969, Mr. Richardson, mayor of New Brunswick, rounded off the 1960s versions of events when, highly dissatisfied with the river's condition, he filed a suit against American Cyanamid:

> Despite repeated notice and knowledge of its illegal and tortuous acts, and well knowing the damage a continuance thereof was doing, the defendant, American Cyanamid, between 1915–1969, persisted in continuing the violations over and over, day after day, and year after year, with a totally reckless and negligent contemptuous disregard of the plaintiff's (the City of New Brunswick) rights, and no thought or care of injury caused to others. It well knew that it never had any right, grandfather or otherwise, to return this water to the River in such a polluted condition that it did, and well knew that after some years of experimentation, that it could never successfully treat its own wastes adequately to prevent pollution. It nevertheless continued what it knew was ineffective treatment with a callous indifference to its effect on downstream potential users concealing as confidential the raw material used, processes employed by it, and capacity and end results. It misled the State authorities and others interested in the purification of the River, press and public alike, to believe it would find a speedy complete and proper solution to this pollution they were causing, when they well knew this was not to happen and could not in any reasonable probability happen or occur. In this they have shown reckless disregard and indifference to the public effort extending over 40 years to clean up this River. It has, to a large extent, frustrated the progress that otherwise could have taken place, and to a large extent has caused the present impasse of conditions on the river regarding pollution and its elimination.[100]

Summary

Since the 1860s, the manufacture of aromatic chemicals in Europe was an activity known to produce considerable quantities of wastes, not just acids and alkalis, but also organic substances that did not break down readily or were refractory. This problem was also encountered in the United States. At Calco, aromatics and other chemicals in liquid effluent changed the appearance of the Raritan River by the end of the 1920s, much to the concern of local and state authorities. Around 1930, state officials inspected the plant's drains and ditches, and Calco scientists undertook studies on the waste. By the late 1930s, increasing production levels led to a situation where the Raritan River provided inadequate dilution levels for effluent. This was especially so during the frequently dry summers. The primary waste-treatment system installed in 1940, while reducing acidity and foam, removing some solids, and controlling the rate at which effluent flowed into the Raritan, did not overcome problems of color, oil, and scum.

Leading waste-treatment consultants such as Rudolfs, Powell, and Mohlman, as well as King and colleagues, undertook surveys and made a number of recommendations, though even these did not deal fully with treatment of refractory waste. Rudolfs investigated long-term stabilization of solid organic matter stored in lagoons at Bound Brook, King suggested that some of the oxygen in the waters of the Raritan could be sacrificed in order to consume organic matter, and Powell worked on treatment with biological sludge. In 1958, the Bound Brook waste-treatment system was supplemented with a biological or secondary process that did overcome some of the difficulties, though it soon proved incapable of meeting increasingly stringent regulations laid down by the New Jersey Department of Health. Certainly it did not remove refractory waste, nor return the Raritan to a state where it could even be classified as a recreational waterway.

Lack of cooperation among municipalities and industries along the upper reaches of the Raritan exacerbated the situation, while criticisms of state agencies militated against considered judgments. American Cyanamid Bound Brook was invariably seen to be the worst offender. Its activities and apparent inaction brought threats of litigation, particularly from communities downstream of Bound Brook, including, at the close of the 1960s, a lawsuit from the City of New Brunswick.

Chapter 13

Activated Sludge to Activated Carbon

"Most of our present water pollution problems have resulted from too little attention in the past. A lack of interest by industry and by the federal government has in the past enhanced the problem."—Joseph B. Zuzick (supervisor, Industrial Hygiene and Safety, American Cyanamid, Stamford), "Research Programs for Air and Water Control," in *Industrial Pollution Control Handbook*, ed. Herbert F. Lund (New York: McGraw-Hill, 1971), 9.1–9.19, on 9.13.

From the 1950s, surface water pollution in the United States often became headline news. Foam from synthetic detergents caused severe problems, including at municipal sewerage works: A particularly spectacular display of foam could be observed off Long Island.[1] In the 1960s, notable events were a fire on the Cuyahoga River, Ohio, caused by oil spills, and extensive fish kills in the Mississippi River from releases of aromatic pesticide chemicals (*ortho*-chloronitrobenzene persisted in the river for about 1,000 miles).[2] The Public Health Service blamed Velsicol's endrin for the death of 5.2 million fish in the lower Mississippi River during the fall and winter of 1963. Occasionally, the 1899 Rivers and Harbors Appropriation Act was invoked to address discharges of effluents into waterways. Meantime, in the absence of federal control, against which the chemical industry had strongly lobbied, in the belief that it could more readily influence—and manipulate to its advantage—the policies of individual states, the burden of dealing with polluters and enforcement fell on the states, particularly New Jersey.

This situation changed following establishment of the Environmental Protection Agency (EPA, founded December 2, 1970), which brought under one umbrella organization groups of programs and offices from several agencies. There followed a proliferation of statutes and acts aimed at combating both water and atmospheric pollution. These included the Water Pollution Control Act of 1972, and its amendment, the Clean Water Act of 1977. Industrial companies that discharged into receiving waters were required to receive state and federal permits and to monitor their effluents.[3] A system of National Pollutant Discharge Elimination System (NPDES) permits was set up to ensure that industry and every publicly-owned treatment works (POTW) monitored effluent and complied with legislation. Other acts included: the Safe Drinking Water Act, 1974; the Resource Conservation and Recovery Act (RCRA), 1976; and the Toxic Substances Control Act (1976). The RCRA came into effect in 1980, when the EPA issued guidelines and regulations on how hazardous wastes should be managed at an existing facility.

Environmental concerns specific to the dye industry included suspected and known carcinogenic intermediates, not just amines such as benzidine and beta-naphthylamine, but a host of other aromatic chemicals that invariably entered waste streams. Further, it was widely recognized that the continuous dumping of industrial waste led to situations where the capabilities of water and soil to degrade it was exceeded. The result was that "receiving streams are predictably losing their capacity to assimilate the increasing organic load being imposed upon them."[4] In those cases in which aromatic waste did not degrade to any appreciable extent there were serious implications for both underground and surface waters.

In 1972, New Jersey became part of the EPA's Region 2 (along with New York, the U.S. Virgin Islands, and Puerto Rico; previously it had been in Region 1). New Jersey introduced complementary regulatory acts, including the Water Pollution Control Act, and Solid Waste Management Act. The New Jersey Spill Compensation and Control Act, passed in 1976, and amended in 1979, became the model for the federal Superfund Act (The Comprehensive Environmental, Response, Compensation, and Liability Act, CERCLA), passed on December 11, 1980. These were followed with the New Jersey Environmental Cleanup Responsibility Act (ECRA), that became effective in December 1983. This aimed to ensure that industrial properties were not abandoned or sold in a contaminated condition.

Confronted with unprecedented adverse publicity during the 1960s, and new regulations during the 1970s, industrial concerns were forced to think hard about how they could respond effectively. The new legislation not only stimulated technical changes in manufacturing processes, the beginning of the so-called "Greening of Industry," it also ensured that pollution was reduced by law and enforced by state authorities. For American Cyanamid Bound Brook this brought new difficulties when the condition of the Raritan River came under even closer scrutiny. Clashes with municipalities and the State of New Jersey, including bouts of litigation and court appearances, became commonplace. To underscore or strengthen their arguments, the warring parties continued to generate partisan histories that read like litanies of either crimes or accomplishments, but that also revealed much new historical detail. Though this sometimes creates difficulties in choosing between conflicting and plausible explanations, it certainly enlivens a history of unattractive spectacles, ambitious targets, failed compliances, notable achievements in waste treatment, and increasingly rigid regulation of industrial wastes. Since regulation transferred the scientific and technical debate to the environmental agencies and law courts, their records contribute much to this history.

The 1970s

The January 1967 amended order gave Cyanamid three years, until January 1, 1970, to complete studies and draw up a construction schedule for an improved biological-treatment plant. Though this requirement was met, the Bound Brook factory, the Raritan, and environs, were kept under constant surveillance, particularly now that the City of New Brunswick had entered the fray. Bioassay experiments conducted by state scientists indicated that fish were unable to survive in the "tea colored" Bound Brook wastewater. Samples were taken of wastewater at various points within the Bound Brook factory, as well as at the Somerset-Raritan Valley Sewerage Authority's plant that discharged into American Cyanamid's secondary waste-treatment system. Foam and dye-colored effluent, including in Cuckold's Brook, were much in evidence.[5] After reviewing an April 3, 1970, report of investigations at Bound Brook, the NJDH supervising engineer, Christian T. Hoffman Jr., decided that the condition of the facility's releases were still inadequate. American Cyanamid was advised by a representative of the NJDH: "I am informed by Chris Hoffman that there is every likelihood that we will be obligated to recommend ... that the above water pollution case be referred to the Office of Attorney General for appropriate action to obtain compliance with our outstanding order ... We are alerting you of this possibility in view of pending litigation that the City of New Brunswick has instituted."[6]

On June 21, 1970, New Jersey deputy attorney general Stephen L. Gordon recorded in a memo: "Inspections, reports and observations by departmental personnel over an extensive period of time show that American Cyanamid has never met the river water quality criteria."[7] One month later, on July 21, he drew the attention of NJDH commissioner Richard Sullivan to Cyanamid's role in bringing about the condition of the river, stated the opinion of Hoffman, and—to improve the situation—recommended that American Cyanamid discharge its wastewater into a new trunk sewer to be installed by the Middlesex County Sewerage Authority (MCSA), and collaborate in a new river study. According to Gordon, departmental personnel had demonstrated that the Bound Brook facility had never met the river water quality criteria.

1. The Corps of Engineers will not build the Crab Island Project until the water pollution is abated in the Raritan River.

2. American Cyanamid, Bridgewater Township, is the largest source of water pollution in the Raritan River.

3. Inspections, reports and observations by departmental personnel over an extensive period of time show that American Cyanamid has never met the river water quality criteria.

4. It is the opinion of Mr. Christian T. Hoffman, Jr., Supervising Engineer, that so long as American Cyanamid discharges its effluent into the river (irregardless of present or future attempts at waste water treatment), FW–3 [recreational and capable of supporting fish] water quality criteria will never be met. Upgrading to FW–2 [potable water] standards would be absurd. Other experts concur with the above opinion.

5. Middlesex County Sewerage Authority is currently preparing final design plans for a trunk sewer to parallel its existing trunk sewer which runs from Sayreville to Bound Brook, N.J. These plans are expected to be completed by December 1970.

6. It is Mr. Hoffman's opinion that American Cyanamid should be directed to discharge its waste water into the MCSA facilities. This would require the diversion of approximately 20 m/g/d from the river but the choice is between 60 m/g/d clean water flow versus 90 m/g/d of substandard water.

7. It is suggested that the Department propose a joint Raritan River study with American Cyanamid and any other interested parties (i.e. the MCSA and the City of New Brunswick) to corroborate or disprove the opinion expressed in paragraphs 4 and 6. Such a study would take approx. 6 to 12 months, depending on available data, and would cost from $12,000 to $25,000.

8. If a joint study is agreed upon, American Cyanamid would have to consent in the form of a court order that it would abide by the results of the said study. Therefore, if the study concluded that American Cyanamid should be out of the river, then American Cyanamid would, by prior consent, take the necessary steps to tie in to the MCSA trunk sewer. If such a study was initiated by the State, the results of this study could be used as a basis for any contemplated court action against American Cyanamid.

9. The alternative to the above river study would be a demand to American Cyanamid that it either meet the Raritan River water quality criteria (which Mr. Hoffman thinks is impossible) or curtail their operations accordingly.

10. The MCSA has a scheduled Commissioners' meeting on July 23, 1970. If you favor the river study it would be advisable to notify the Authority [MCSA] as soon as possible so that their plans might include the possibility that American Cyanamid will join its trunk sewer.[8]

Nothing came of these proposals. A few weeks later, A. Bruce Pyle advised Hofmann that his samplings of Cuckold's Brook revealed high levels of contamination entering the river.[9] Subsequently, Pyle and colleagues reported that there had been no detectable change in the condition of the Raritan during the previous five years (1965–70), and "fish life has been, and continues to be, detrimentally affected to a substantial degree." Pyle quoted from his 1965–66 study: "The effluent from the American Cyanamid–Somerset-Raritan Valley Sewerage Authority sewage treatment plant has a substantial effect upon the physical, chemical and biological characteristics of the Raritan River over a minimum distance of from 2,500 feet to 12.2 miles." He then suggested that the similarity of these results with more recent findings "indicate that there has been no improvement in the effluent with regard to its maximum toxicity. And since it is the maximum toxicity of a waste that largely determines the character of the fish population in the receiving stream, it is concluded that the results and conclusions of the 1965–66 study continue to be valid."[10]

More difficulties were in store for the Bound Brook facility after NJDH surveillance revealed that excavation was under way for a new, but apparently unauthorized (as was now required), waste impoundment. Hoffman wrote to plant manager George Hedden: "Construction of a large lagoon has been noticed by representatives of this Department in the vicinity of the American Cyanamid Secondary Waste Treatment Plant. In the event that this lagoon is an addition to the plant's water purification system, the American Cyanamid Company is in violation of State law: Water and Sewerage Statute R.S. 58:11–10." In addition, Hofmann continued, "[o]ur investigation indicates that the discharge from Cyanamid's wastewater treatment plant is polluting the Raritan River. We will recommend that legal action be taken to abate this pollution."[11]

Hedden advised Hoffman:

> In response to your letter dated October 22, 1970 and received by us on October 27 regarding the recently constructed large lagoon on this company's property, this lagoon duplicates a similar installation, now full, used for many years for the impounding of the inert sludge generated in the neutralization step of our primary treatment plant which commenced operation in 1940.
>
> We recall giving you this explanation on two previous occasions when you were here at the Bound Brook plant, June 22 and June 30, 1970. The question of a permit was not raised at our meeting in Trenton [the offices of the NJDH] on July 28 and we therefore assumed that the matter was considered closed.[12]

Early in 1971, responsibility for clean air and water in the State of New Jersey was transferred from the Department of Health's agencies and divisions to the newly-formed New Jersey Department of Environmental Protection (NJDEP). In May 1971, the results of tests on Bound Brook waste by Pyle's bureau were discussed. They "indicate rather solid evidence that the company is not meeting quality standards ... Frederick B. Lacey of Shanley & Fisher, counsel for the company ... claims the company has a right to deposit pollution in the river as long as it does not substantially impair the quality of water and that the effluent they are putting in now does not substantially impair quality and they have a right to dump it in the stream."[13]

Also in May, an American Cyanamid report, "A Program to Further Characterize the Effluent from the Secondary Waste Treatment Facility at Bound Brook, New Jersey," defended the corporation's strategy in the light of expanding industrial and population growth. The document was drawn up in response to a meeting held in Trenton on April 13, 1971, when representatives from the NJDEP indicated that, based upon their tests in the vicinity of the Bound Brook waste-treatment operation, American Cyanamid was not meeting the literal requirements of the 1966 order regarding stream quality criteria. The NJDEP suggested two possibilities for putting things right: "First, to change the nature of the effluent, or second to change the point of discharge of the effluent." It then drew attention to Cyanamid's standpoint. The American Cyanamid report

challenges the department's findings as well as its conclusions and goals. First, the report contends that under the current circumstances, "it is not reasonable to require, nor is it economically feasible to attain, river water of a quality suitable for all purposes ... The quality of the water in the Raritan River presently classified as FW-3 is good. However, to expect this section of the river to be suitable for recreational purposes and to support fish life at all times is unrealistic and incompatible with the tremendous expansion of industry and the crush of a rapid population increase the area is experiencing. Logically, it does not make economic sense to expect all areas of the stream to serve all purposes."[14]

On May 25, Steven Lubow, NJDEP assistant biologist, Division of Water Resources, and Robert Koteh, field worker, Public Health, sampled Cuckold's Brook and the Raritan River downstream of the factory:

In the vicinity of Queens Bridge seven to eight dead Catostomi (suckers) ... were observed. At the time of the observation the area under Queens Bridge had an accumulation of scum similar in color and nature to that observed after the discharge of waste from American Cyanamid, in Cuckold's Brook. The dead fish appeared to have been dead for some time as fungi were already at work on them.[15]

Also investigated was the difference in the aquatic species composition and number above and below the Calco Dam. In June, 1971, "A Survey Investigation of the Raritan River at Bound Brook," was conducted to "serve in part to further document or otherwise refute previously reported conditions." The river below the American Cyanamid–Somerset-Raritan Valley Sewerage Authority

is generally unsuitable for fish life ... Considering the intensity of the organisms represented at the various [survey] Stations it is evident that typically pollution-tolerant species, such as Tendipedidae [midges] and Tubificidae ["sludge worms"], make a significant jump in their population density below the American Cyanamid Dam. This would suggest that while the conditions are unfavorable to fish life and many aquatic macroinvertebrates normal to the Raritan River, there is selective benefit to these two organisms ... Based upon the combined results from in-situ and static fish bioassays, as well as the results from benthic macroinvertebrate sampling, there appears reasonable evidence to conclude that the Raritan River area below the American Cyanamid Dam represents a degraded aquatic habitat ... It is further evidenced, based upon in-situ fish bioassay results, that the character of the River below the American Cyanamid Dam is toxic to a variety of fish species normally found at the [upstream] confluence of the Raritan and Millstone Rivers. Based upon the data from the static fish bioassay, it is further evidenced that a toxic character originates in Cuckold's Brook after its receipt of effluents from the American Cyanamid–Somerset-Raritan Valley Sewerage Authority. Similarly, through the static fish bioassay tests and subsequent TL_m [median tolerance limit] determinations, it is indicated that this toxic character is capable of exerting a long-term toxic state in the receiving waters of the Raritan River. Based upon these evidences, as well as those cited in the aforementioned report [August 1970], it is concluded that the effluents from the American Cyanamid–Somerset-Raritan Valley Sewerage Authority persist in being a major detriment to the aquatic life normal to this drainage area by virtue of its toxic character.[16]

Two months later, in August 1971, Hurricane Doria hit the Bound Brook plant. Some sixty percent of products and raw materials in the warehouse were destroyed, much of it subsequently dumped in lagoons. "Nothing like it had been seen since September 1938." It took until October before the factory was almost back to normal. At the end of October, Hedden advised NJDEP commissioner Richard

Sullivan that changes in the secondary treatment plant had brought about "the desired substantial increase in BOD removal efficiency … and the secondary plant has operated at monthly average efficiences as high as 96.2% vs. prior monthly averages in the mid-80%." However, and with the findings of the Bureau of Fisheries in mind, Hedden added that "there have been allegations concerning the quality of our effluent in other respects."[17]

From around this time the EPA became more involved. Measurements by its scientists indicated that Bound Brook released 0.14 lb. of mercury daily with its aqueous effluent.[18] In October 1971, American Cyanamid made a commitment to eliminate releases of mercury. It had been used at Bound Brook in the manufacture of vat dyes until around 1970, and subsequently only in the production of Cyanacryl elastomers.[19]

In April 1972, in preparation for a further round of litigation, Donald J. Jacangelo, assistant fisheries biologist, Division of Fish, Game and Shell Fisheries, NJDEP, drew up an affidavit in which he summarized his conclusions regarding the toxicity of Bound Brook effluent. These agreed with the division's earlier findings.

> A study was initiated by me in order to update the Division's information on the Raritan River concerning the impact of the American Cyanamid discharge upon the river biota. The study area encompassed a point immediately below the confluence of the Raritan–Millstone Rivers downstream to the Fieldville dam. Cuckold's Brook was also included in this study. The study began on June 22, 1971 and was concluded on June 29, 1971 … After analyzing all the data of this study I concluded that the American Cyanamid waste was toxic to the fish life in Cuckold's Brook and was toxic to fish life and aquatic biota of the Raritan River below the American Cyanamid dispersion dam. This information corroborates and updates the conclusions of the 1965–1966 Raritan Study conducted by our Division under the direction of A. Bruce Pyle.[20]

American Cyanamid was again taken to task over the, apparently, continuing toxicity of its effluent. On May 3, 1972, Hedden was advised by Charles M. Pike, director, Division of Water Resources, NJDEP: "This letter is to notify you that the Department of Environmental Protection has referred to the Attorney General's office a recommendation that court action be instituted in connection with the discharge from your wastewater treatment plant." Hedden was reminded that on June 24, 1971, Stephen Gordon had written to American Cyanamid about its effluent, and that "Mr. O'Brien of your legal department responded on August 16, 1971 that the proposed solution to your wastewater problem which you were pursuing was to join the regional Somerset-Raritan Valley Sewerage Authority ... Since your negotiations with the regional authority have not been finalized, we are referring this case to the Attorney General's Office for appropriate court action."[21]

The 1972 Water Pollution Control Act imposed secondary treatment as a general standard on water and wastewater treatment works. In the case of Bound Brook, however, the impact, which included enhanced NJDEP involvement, was to be far greater. This happened after American Cyanamid's troubles entered a new phase—one that would force a completely changed approach to effluent treatment—when the NJDEP filed a complaint before the Superior Court of New Jersey, Chancery Division, Somerset County. The charge, as delineated in docket number C–2883–71, of May 17, 1972, and heard before the court in Somerville, was that:

> the defendant has not complied with a pollution abatement Order and an Amended Order of the Department in violation of N.J.S.A. 58:12–2 and 58:12–3; and it further appears that the defendant is discharging inadequately, insufficiently and improperly treated industrial waste waters and other polluting matter from its treatment plant into the waters of the Raritan River and its tributaries in violation of the standards of quality established therefor by the State Department of Health (now the Department of Environmental Protection).[22]

The NJDEP's complaint dealt with three issues: the quality of effluent; installation, without authorization, of the new sludge lagoon and a sewer line; and groundwater contamination.[23] The court ruled against American Cyanamid. The NJDEP was granted injunctive relief, that is, the right to enforce on American Cyanamid compliance with the relevant laws of the State of New Jersey.[24] The corporation was also ordered to comply with specified effluent standards.[25] It had to undertake analytical measurements to determine the nature of the "toxic and/or deleterious substances, their effects, and monitor the toxicity of their effluent ... [and] run 96-hour static bioassays with daily renewal of test solutions utilizing fat head minnows (*Pimephales promelas*). Testing of native organisms to determine the most sensitive organism, for ultimate use in determination of safe discharge volumes, will proceed as part of all bioassays run on the effluent." Also, Cyanamid "must implement and operate flow-through bioassays within 45 days of the entry of this order." More challenging was the next demand: "Concurrently with bioassays, American Cyanamid shall conduct a program of chemical analysis to identify the toxic components, and their origin, of their effluent." Cyanamid was required to "furnish to the State, on a monthly basis, all records, results and reports concerning analysis used in implementation of this order."[26]

Two counts of the complaint concerned the absence of approval for laying down a concrete sewer pipe and of a permit for excavating the new sludge lagoon. As a result, the Court ordered Cyanamid

> to clean and cover all those lagoons leaching pollutants into the Raritan River ... [to] initiate a survey to determine the extent of groundwater pollution resulting from the sludge, liquids and solid industrial wastes heretofore deposited in the aforementioned lagoon ... [and to] obtain a permit from the Department pursuant to N.J.S.A. 58:11–10 and 58:12–3 if any lagoons are to be used as a part of its waste water treatment facilities.

Faced with this barrage of demands, American Cyanamid mounted what was to be its final offensive, based on treatment of liquid waste with activated carbon, that is, advanced waste water treatment (AWWT), or tertiary treatment. While this was by no means a totally new concept, American Cyanamid decided that it was time to test the technology at its limits.

Tertiary Treatment

Filtration of water through activated carbon had been used in Britain since early in the 20th century for removal of taste and odor-causing organic compounds from potable supplies. In 1929, powdered activated carbon was employed at just two municipal water works in the United States; success was such that in the early 1930s it was in use at around four hundred water works. Since surface waters required for drinking purposes were becoming increasingly contaminated with industrial wastes, activated carbon replaced sand as the filter medium of choice. As early as 1919, E. J. Casselman of the Public Health Service investigated the use of activated carbon in the treatment of Rahway River water contaminated with dye-making waste from a factory at Rahway, New Jersey. From 1931, an improved powdered activated carbon was employed in treating water contaminated with the same waste, after coagulation, at the Rahway water filtration plant. "These wastes and storm water contamination from saturated ground adjacent to their source contained phenols, aniline, nitrobenzene, and nitrotoluene reduction products [toluidines]." Removal of constituents responsible for taste and odor was more successful than any other process, though it "may be very expensive during periods of severe pollution. The average cost of plant treatment over a period of 12 months was $1.73 per million gallons of water treated. The maximum cost was $8.35 per million gallons of water treated."[27] Activated carbon had been used increasingly since the 1950s at the Elizabethtown Water Company works, just upstream of the Bound Brook manufacturing area. It was responsible for the supply of a clear, colorless potable water.[28]

Large-scale treatment of industrial wastewater containing aromatics with activated carbon was first employed from 1954 at Fisons Pest Control, Ltd, Harston, Cambridge, England, for removal of phenolic compounds.[29] At Harston, the activated carbon, held in towers, was employed in pre-treatment. Later processes employed the carbon in final, or tertiary, treatment. One reason for the Harston arrangement was that it protected the system from sudden shock loads (the activated sludge processes worked best with low and steady concentrations of organic refractories). Despite the cost of the adsorbent, several laboratory and pilot plant experiments, particularly in the United States around 1970, demonstrated the potential offered by powdered activated carbon when added to activated sludge in industrial biological wastewater-treatment processes, particularly when dye wastes were present.[30] This was the basis of the DuPont Powdered Activated Carbon Treatment (PACT) process.[31] In this, the carbon was discarded with the waste sludge. An alternative was to force biologically treated and filtered wastewater up through towers filled with granulated activated carbon. This was the advanced waste water treatment (AWWT). It had the advantage that it could be made continuous, with the spent carbon recovered and reactivated for further use. In 1961, it appears, the first water works in the United States was converted from powdered to granular activated carbon, and by the early 1970s, some four hundred works were using the granulated form.[32] At the end of the 20th century the granular activated carbon process would be recommended for wastewater treatment in preference to the addition of carbon during secondary treatment. In the 1970s, however, the latter was generally preferred, in part because treatment was simpler and more rapid. A leading promoter of activated carbon in the United States, as well as in Britain, was the Calgon Company, that offered a range of coal-based granular activated carbons.[33]

In June 1972, Bound Brook's Hedden outlined American Cyanamid's new strategy to Sullivan, the NJDEP commissioner: "We present herewith a planned Advanced Waste Water Treatment Program (AWWT) which will substantially upgrade the quality of the effluent from our secondary activated sludge waste treatment facility ... American Cyanamid Company is confident that this AWWT program reflects a true demonstration of its determination to cooperate and apply its technologies and its energies on behalf of the public concern. Furthermore it is our belief that this plan of action will wholly satisfy the objectives of the Department with respect to the attainment of stream quality criteria."[34] On September 13, NJDEP engineer Richard Delgado commented on the response from Cyanamid: "This letter [from American Cyanamid] indicates that the effluent from such a plant will be 'odorless, essentially water white, nontoxic.' Unless the intent of the company is to produce an effluent of the same quality as the Raritan River above Cyanamid's discharge, the company should define the effluent goals in a quantitative manner."[35] Notwithstanding any doubts, the AWWT project—the outcome of the charges brought again Cyanamid in May—became the principle feature of the program drawn up to satisfy the requirements of the NJDEP. If successful, it would remove both refractory organics and trace metals.

In May 1973, a group from the New Jersey branch of the American Institute of Chemists visited the Bound Brook effluent treatment plant. Participants were advised: "At Bound Brook, the American Cyanamid

Company operates the largest privately owned biological waste treatment plant in New Jersey, providing secondary treatment for the waste water from the company's complex organic chemicals manufacturing facility, and for a primary effluent from a nearby municipal authority serving a population of 55,000 and several large industries."[36] The annual cost of operating the wastewater-treatment plant was $2 million. The visitors observed pilot-plant work on two activated carbon-treatment processes, one with columns (described as the Calgon plant), as later adopted at Bound Brook, and the other with addition of activated carbon to the activated sludge. Anton C. Marek Jr., chief sanitary engineer since 1970 (he joined Bound Brook in 1962), was on hand to explain the studies to guests, which included representatives from the Toms River Chemical Corporation, the CIBA-Geigy vat and azo dye and resins factory.[37] Both sites, Bound Brook and Toms River, confronted similar environmental problems, particularly since they were situated next to small rivers (in 1966, Toms River began discharging treated waste to the Atlantic via a pipeline). It was probably from this time that American Cyanamid Bound Brook and Toms River Chemical, which had previously exchanged information concerning atmospheric pollution from their facilities, began to share their experiences with solid and liquid waste treatment.

On October 12, 1973, a formal agreement, a stipulation and consent judgment, was entered into between the NJDEP and American Cyanamid, in order to settle the May 1972 suit. This involved the introduction of tertiary treatment in two phases. Phase I directed American Cyanamid to design, construct, and start an AWWT pilot plant employing multi-media filtration and activated carbon, maintain round-the-clock operation of the pilot plant, undertake data analysis, and prepare preliminary design and engineering for the full-scale plant. This work was scheduled to be completed by January 1974. Phase II involved "final engineering, including completion of specifications, selecting bidders, preparation of contracts and selection of contractors, plant construction," and start-up, by October 1976. The stipulation and consent order required American Cyanamid "to investigate all manufacturing buildings to characterize each emission and to design and install abatement equipment for each emission found." In addition, the corporation had to "undertake studies of alternative methods to eliminate its on-site treatment lagoons or to protect those lagoons from infiltration during flooding, and to eliminate any intrusion into the groundwater of the sludge and wastes contained in the lagoons."[38]

The great concern shown among different communities along the Raritan River with the impact of Bound Brook effluent made it a suitable topic for a Ph.D. dissertation.[39] This provides a useful independent description of various facets of the interaction between Bound Brook effluent, the Raritan, and its physical environment during the early 1970s, and no doubt also until the middle of the decade. "Cyanamid's effluent is discharged into Cuckold's Brook which flows into the river. Before it reaches the river, however, it flows into a pipe which carries it into a dispersion dam ... There are 41 eight-inch diameter ports approximately 3 feet apart in the low central section of the dam. Cyanamid claims that the elbow turns allow the pipe to fill up across the river and then overflow so the discharge is uniform across the river and not concentrated at the far end. However, on-site inspection showed many ports to be clogged."[40] The following extracts, impartial insofar as they neither emanate from American Cyanamid nor a state or federal agency, summarize the situation downstream of Bound Brook.

Cyanamid claims that their pollution is fairly constant. However, such is not the case ... the variability [as measured by maximum concentration/minimum concentration] increased dramatically downstream from Cyanamid. Thus, two grab samples (as done by Cyanamid) are totally inadequate to provide an average concentration for their effluent ... sampling only on two days, as they did for their report to the Army [Corps of] Engineers, is totally inadequate. This caused them to misrepresent their intake and discharge. They generally overestimated the components of the incoming water and almost always underestimated the components of their discharge ... This double mistake means they have seriously underestimated their pollution.[41]

However, these problems do not conceal the overall effect of Cyanamid's pollution. The lower water quality below Cyanamid is dramatic.[42]

On many days, the condition of the river is much worse along the north bank downstream from Cyanamid ... Similar calculations with the water quality data taken for the thesis also showed higher variability below Cyanamid.[43]

Cyanamid's effect on the DO [Dissolved Oxygen] concentration in the river is the greatest in the summer.[44]

As a result, large numbers of pollution-tolerant organisms, particularly tubifex ("sludge worms"), in July, and tendipes (midges), in August, were observed. "At the three stations by Queen's Bridge, either one or the other of these organisms comprised over 90% of the sample by weight. As far as dominance in numbers [is concerned], the figure is even more striking, 95% ... Mayfly larvae, as a whole, are pollution intolerant organisms. They show a decrease in numbers downstream from Cyanamid ... However, they are also much more prevalent upstream of Cyanamid in August than July ... Different generations probably respond in different ways to pollution ... Tubifex and Tendipes are pollution tolerant organisms. They are more prevalent downstream from Cyanamid."[45]

Continuous monitoring would also benefit Cyanamid. If the data that was presented to the Corps of Engineers represents their best data, then Cyanamid has no accurate idea of what their effluent contains ... This work has demonstrated that Cyanamid's pollutant discharge is not constant. This thesis has defined Cyanamid's effluent better than has been done previously ... [T]he river below Cyanamid is not fit for swimming or fishing and is not conducive to canoeing or boating. Often it has a stench all of its own ... Fishing above Cyanamid is a regular occurrence. The fishermen claim to enjoy eating the fish. There are fish below Cyanamid; however, only one fisherman admitted to ever fishing below Cyanamid. He has never fished there again, as the fish had a very unpleasant odor to them after cooking.[46]

In contrast to DuPont's large Chambers Works at Deepwater Point, New Jersey, situated in isolated farm country next to a river forty feet deep and half a mile wide, as Isaiah Von emphasizes, Bound Brook was not only sited next to a small river but, from around 1960, also in an area of high population growth. This made the pollution problems of far greater consequence.

Back in the Superior Court of New Jersey

There is no doubt that American Cyanamid took pollution abatement seriously. In August 1973, *Cyanamid News* featured extensive coverage of environmental programs, including "major air quality improvements" at Bound Brook, where a new Clean Air Task Force dealt with emissions from batch operations.[47] Nevertheless, there was need of repairs. For example, a Mr. Reed of the NJDEP noted: "On June 11, 1974, this writer accompanied Mr. Tom Vernam on an inspection of the sludge-holding ponds on the property of American Cyanamid, Bound Brook … A section of the berm is broken and during a rainstorm some of the material is washed away, eventually into the Raritan River."[48]

In November 1974, the EPA issued Bound Brook with a National Pollutant Discharge Elimination System (NPDES) permit setting standards that could only be met by activated carbon treatment, and stipulating suitable disposal of secondary sludge. The permit also specified that mixed rainwater and effluent could not be short circuited to the Raritan River, as was then current practice. Early in 1975, New Jersey deputy attorney general, and chief of its environmental protection section, Morton Goldfein verbally granted American Cyanamid an eight-month extension of the time schedule specified in the 1973 consent order, to enable completion of pilot-plant studies. Ben Loper, in his February 1975 prospectus to the American Cyanamid executive committee, strongly recommended that Bound Brook adopt the AWWT process. He pointed out that the pollution load came generally from all products, and there was no practical way of discontinuing manufacture of a few products and continuing with the others. Moreover, "[w]ith a carbon treatment facility and the protection of the Consent Order, Bound Brook may have unique advantages in manufacturing many products, especially those with troublesome effluent. As an example, the new Tobias acid facility will be proposed for Bound Brook, not Willow Island, specifically because of effluent disposal problems."[49]Activated carbon would enable American Cyanamid to meet federal requirements, argued Loper, particularly since the EPA considered this means of tertiary treatment the best available technology economically. Two other large New Jersey dye-manufacturing facilities, DuPont's Chambers Works and Toms River Chemical, were already preparing to install activated carbon treatment.

Later in the year, however, Goldfein concluded that Bound Brook was not acting in accord with the NJDEP's requirements, which included the supply of samples and bioassay test data from the pilot plant, neither of which were forthcoming. In September 1975, the parties were back in the Superior Court of New Jersey. The affidavits of defendants and plaintiffs, discussed at a hearing on September 30, are interesting for the additional background details that they reveal, particularly as to how both sides perceived levels of communication, or at least lack of it.[50]

American Cyanamid defended its motion for an extension of time through reference to its massive financial commitment, and the authorization on March 25, 1975 of upgraded effluent treatment facilities by the Board of Directors, at a cost of $22.4 million.[51] Development work on the AWWT system had commenced in 1972, and during the following two years some nineteen man-years were devoted to the project, including by engineers, laboratory technicians, and researchers. It was anticipated that during 1975 an additional six man-years would be required to complete the pilot plant program, Phase I. This would be followed up with engineering and design of the full-scale plant. By the end of 1974, the cost had reached $360,000. It was estimated that the pilot plant work would require a further $180,000 during 1975.

Support for American Cyanamid came from the affidavits of Clifford W. Bowers, project manager of Metcalf & Eddy, Inc. (Boston), which had developed the carbon adsorption design, Edward J. Volke, project engineer responsible for developing construction schedules on major capital projects for Metcalf & Eddy, and Stuart S. Speter, of Nichols Engineering and Research, of Belle Mead, New Jersey, supplier of the carbon regeneration equipment. Volke devised the schedule for design, engineering, procurement, and construction of the Bound Brook AWWT plant. The project required twenty-four months to develop a construction schedule and several months to finalize contracts, plus a six-month start-up period. Speter, who represented process management at Nichols, explained that hearth furnaces for both activated-carbon regeneration and secondary-sludge incineration were required. It would take around twenty-one months to erect structures, plus three months to complete power wiring, painting, and debugging equipment, a total of 24 months.[52]

For the plaintiff, Stephen Lubow reported: "Based upon sampling of numerous industrial discharges in the State, review of bio-assay data obtained by staff of the Department, and evaluation of the impact of this facility's discharge on its receiving streams, I have concluded that defendant's discharge has been and continues to be the single most significant source of toxic waste into any fresh water stream of the State of New Jersey." The defendant, Lubow pointed out, was asked to furnish "samples of the output of the pilot plant ... we have never been furnished such samples."[53] Jeffrey Zelickson, deputy assistant director, Division of Water Resources, NJDEP, claimed serious failures by Cyanamid in maintaining mandated water quality standards and in keeping to stipulated schedules.[54]

The main hearing, in November, offered another version of the recent history of waste handling at American Cyanamid's Bound Brook facility. The corporation stated that it could not adhere to the court-imposed timetable (called Exhibit B), and requested an extension of the completion date for the entire project, Phases I and II, from October 1976 to December 1977. The NJDEP opposed the extension. However, it suggested, if an extension was to be granted then the consent judgment of October 1973 should be amended in order to establish further safeguards whereby the department could monitor progress. The court observed that originally "the pilot plant procedure was to start up in October 1972. According to Mr. Marek, [it] actually did start up possibly even in September, but undoubtedly in October of 1972." It was intended that the pilot plant should operate for twelve months, with another month for review of data and establishing the economics of carbon regeneration and the overall efficiency. Moreover, "[a]ccording to timetable, those parts of Phase I were to be completed in January 1974. The testimony is clear, [that] they were not completed until April of 1974."

The reason for the extra time, according to American Cyanamid, was a substantial loss of carbon in the first two pilot plant runs. In June 1973, Nichols indicated that the loss ranged from 30 to 50 percent, which if not reduced would make the process economically unfeasible. These high, and excessively expensive, carbon losses were unanticipated by American Cyanamid's engineers, since, as Marek pointed out, the effluent task force had earlier found losses of about 10 percent. There was also uncertainty as to the probable level of loss when carbon regeneration was carried out on a larger scale. In general during regeneration, waste treatment plants reported losses of 2 to 10 percent of the carbon. Losses had occurred in both carbon volume and adsorptive capacity. Nichols recommended further tests.

When American Cyanamid entered into the consent judgment in October 1973, the schedule indicated that only two more months were required for the continuous operation of the pilot plant, and conclusion of Phase I. They had in fact entered into the judgment "without knowing how long it was going to be before the final testing of this carbon regeneration loss situation would take. According to Mr. Loper they made a business compromise. It hardly seems to meet the standard of an unforseen contingency contemplated by the parties." Phase I was completed several months later than scheduled, in October 1974. By that time, the court observed, the "project had grown far beyond the anticipation of the defendant ... They have the right under this contract to review both technical aspects and the economic aspects to make their own decision about proceeding." Cost overruns were substantial, with "escalation from ten to twelve to all the way up to $30 million." American Cyanamid "obviously had second thoughts and decided they might reconsider the entire program and, therefore, had further studies made to determine the economic feasibility of this particular program." This, according to the court, "was something that would not have been reasonably forseen by the defendant and ... the delay ... was not within the defendant's reasonable control."

This was certainly an even-handed appraisal, which apart from scoring American Cyanamid for delays, and criticizing both parties for lack of cooperation, implied a certain lack of sincerity of purpose that could have been overcome through greater willingness to consider each other's views. The court found little evidence of any useful exchanges, only suggestions of lack of communication, and of arm's-length dealing. "The court doesn't suggest it condones the actions of the defendant in deciding arbitrarily that it was not going to give results of the bio-assay test, for instance, because the plant was not operating at normal capacity. It seems to the court a condition would have been imposed on any results submitted to the plaintiff. But the plaintiff possibly in its desire to have the river cleaned up as quickly as possible—possibly because of the arm's-length relationship—didn't really pursue this matter diligently as the court thinks it should have."

Moreover, the question of the level of expertise in bulk use of granulated activated carbon treatment was raised, as was the related problem of adhering to imposed schedules for an as yet unproven technology when conducted on a large scale for industrial purposes. It was acknowledged that in 1972, when this method of waste treatment was being considered by American Cyanamid, the "state of the art as pertains to granular carbon adsorption was extremely limited. The knowledge of the experts was almost entirely restricted to the use of that procedure in municipal waste treatment systems rather than industrial." On this basis, the court found that the additional time for plant construction arose from factors that were not "within the reasonable control of the defendant. The testimony is clear that the defendant is proceeding at this time expeditiously." The alternative to granting an extension "would appear to cause the defendant to be subjected to overwhelming economic sanctions. And I am not losing sight of the fact that we are primarily concerned here with the condition of the Raritan River, nor am I arriving at this decision succumbing to any economic—I don't want to use the word blackmail, the word is too strong—pressure by their suggestion [that] they will close down and put out of work 2,500 people. It just doesn't leave to me any choice either on a legal basis or on an economic basis or on an equitable basis."

The decision was that delays had occurred without improper activity on the part of American Cyanamid; the delays were beyond the reasonable control of the corporation. The NJDEP had not acted reasonably in denying approval for an extension of time. The consent judgment was amended to enable completion in December 1977 instead of October 1976. American Cyanamid was ordered to supply the NJDEP with data, and progress reports, at three-month intervals, instead of at six-month intervals, as previously. The court also alluded to fines if works were not finished according to the new timetable, Phase I by the end of December 1975, and Phase II by the end of June 1977, with full-scale operation commencing in December 1977. "It seems to me that at the time when any one of these deadlines is reached and passed without work being completed the amount and type of sanctions would depend on just how dilatory or how diligent the defendant has been. It certainly doesn't seem there ought to be a definite amount now. I won't agree to include that in any amendment in the judgment, Mr. Goldfein."[55]

Chapter 14

The Advanced Wastewater Treatment Plant

"American Cyanamid had fought tooth and nail every step of the way against the New Jersey Department of Health (and later the Department of Environmental Protection), but once they did something it was a showplace, the state of the art."—Erwin Klingsberg.

Ben H. Loper's February 1975 prospectus, the important policy document that we met in earlier chapters, represented American Cyanamid's internal response to the requirements of the October 1973 consent order and the November 1974 National Pollutant Discharge Elimination System (NPDES) permit. They mandated installation of an activated-carbon system to treat liquid effluent, and facilities for incineration of accumulated sludge from secondary treatment.[1] Loper's document was drawn up in order to gain specific support and approval from among certain manufacturing divisions for the installation of tertiary wastewater treatment and associated plant at Bound Brook. Loper recalled that the facility had been sued on May 17, 1972 by the State of New Jersey for "alleged pollution of the Raritan River." This had elicited an immediate response from American Cyanamid, namely a "plan of action" involving studies based on activated carbon. Pilot plant work on the activated-carbon process demonstrated that it represented the best available existing technology for removal of "objectionable toxic organic compounds, color, suspended solids (sludge carry-over), foam, etc." Moreover, in 1975, five-sixths of the excess sludge generated in the existing secondary biological-treatment plant was discharged to the river as suspended solids. The proposed new hearth-sludge furnace would consume this material as well as unrecoverable waste solvents and tars from production operations.[2]

Projected manufacturing changes designed to reduce the pollution load had been "calculated on the basis of a theoretical material balance made up of the top 52 polluters which accounted for 83% of the TOC [total organic carbon] load measured at the effluent plant in 1974. Without BN [beta-naphthol] and derivatives, which are major sources of pollution being phased out in 1975 [and transferred to Willow Island], the 50 top TOC contributing processes in 1974 account for 77% of the remaining TOC pollution, with the top 20 equaling 73%." These top twenty polluting processes, "however, eventually result in about 400 finished products, not counting blends, out of about 1,000 products at Bound Brook."

A report on the feasibility of continuing the dyes business, particularly in view of the effluent problems, was scheduled to be ready on April 1, 1975. For the purpose of the prospectus, the economic projections were based on the assumption that only certain basic and solvent dyes, four vat dyes, and nigrosines would be continued. This would bring about a small reduction in the TOC load. While trading conditions led to plans for downsizing by twenty percent at Bound Brook, growth was expected to take place at an annual rate of three percent after 1983. To handle this "we fully expect to make further process improvements and, only if unsuccessful, to discontinue low-profit items as needed to operate within effluent plant capacity." The possibility of discontinuing "the complete Dyes, Intermediate Chemicals and Pigments Departments instead of reducing individual processes and products with high pollution loads or low profits" was considered, but rejected since this would have led to minor capital savings and considerable loss of profits. In any case, the new waste-treatment plant was expected to remove liquid effluent problems once and for all: "The present treatment plant neutralizes the effluent, settles out solids, and removes biologically around 65% of TOC. The proposed new carbon treatment facility has only to filter the biological sludge and remove the remaining 35% of TOC."[3]

After discounting the possibility of relocation elsewhere, in part because of major new investments in nigrosine and Tobias acid plants—and taking into consideration plans for expanding production at Bound Brook for Lederle Laboratories—Loper commented on at-source activated-carbon treatment of liquid effluent, instead of "end-of-pipe" treatment of the effluent. The former was not a practical alternative.

We examined treatment with neutralization and carbon adsorption at-source instead of final treatment after the effluent leaves the operation. The capital and operating costs would be over three times higher. A final treatment plant capable of handling the total effluent flow would still be necessary to handle contaminated rainwater, spills, leaks, individual unit malfunctions, etc.

Sludge from secondary biological treatment and primary settling required new storage basins: "The composting basin" for biological sludge "has been filling for 27 years and has about 3 to 5 years more of operation. Subsequently, a new basin for which land exists will need to be constructed at a cost of $1–1.5 million." As for sludge from the primary settling basin, the "new primary sludge storage lagoon is about ready ... In 7 to 10 years, it will be full and another lined lagoon, at a cost of $1 million, will be needed. Land is reserved for this use past the year 2000; however, engineering is under way to examine better sludge disposal methods."[4]

All these initiatives were justified by the profits generated from processes responsible for the heaviest waste loads, those based on the aromatic intermediates, whose main use was no longer in production of colorants: "The average profitability of the products made in Bound Brook exceeded the all-company average in 1974. About two-thirds of the pollution load comes from the two strongest businesses—Pharmaceuticals (chiefly the Agricultural Division) and Rubber Chemicals (Elastomers and Polymer Additives)."[5]

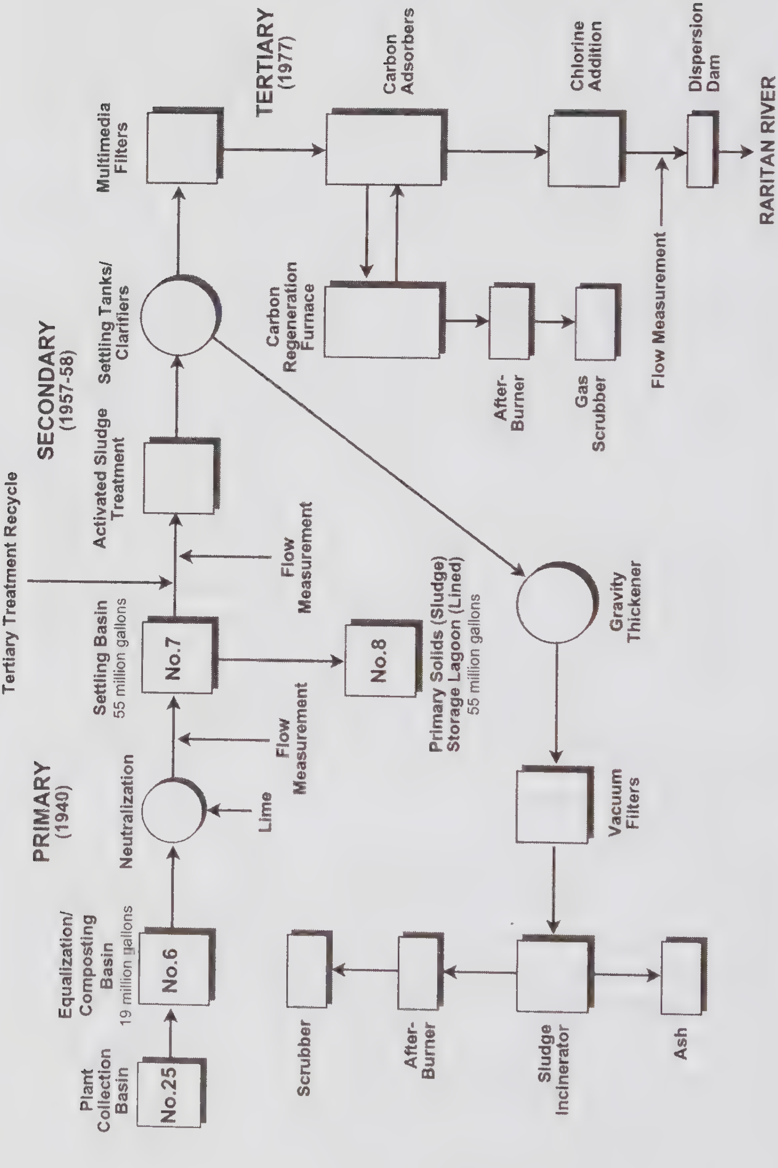
There was considerable optimism that the AWWT plant would serve as a model for other sites, as well as ensuring the long-term retention, and even expansion, of Bound Brook: "As the first large installation in Cyanamid, the carbon adsorption plant will act as a pilot facility for other plants and may be important for new products with troublesome effluent. With a permit to discharge dissolved solids, a location only 3.1 miles from salt water in a river classified as nonpotable, recreational water, and with adequate site support facilities, Bound Brook may become the location of choice for new products and expansions. Preliminary tests showed that the survival rate of fish in 100% effluent from the pilot-carbon treatment unit has been better than in the incoming river water. The public relations value is obvious."[6] The sludge disposal and AWWT facilities were designed to handle, respectively, 15,500 lbs. per day of waste activated sludge by dewatering and incineration, and 20 million gallons per day of secondary effluent by carbon adsorption, assuming an average TOC loading of 14,600 lbs. per day and a maximum of 19,000 lbs. per day. "These loadings are based on normal operation of the biological treatment plant."[7] In support of these recommendations, Loper then drew upon management opinions gathered from other divisions. There was overwhelming support for the tertiary treatment plant and retention of the Bound Brook facility.

On February 24, 1975, J. Ludden advised Loper, "We share your recommendation that the best alternative is to equip the Bound Brook Plant with proper effluent treatment to comply with regulations. A shutdown or a move elsewhere are not realistic." From Wayne two days later, H. F. Bliss Jr., wrote: "This Division [OCD] supports your prospectus for the tertiary carbon adsorption effluent treatment project at Bound Brook." This was endorsed by G. P. Bywater, on February 28, 1975. From Pearl River, Jan Dlouhy, observed:

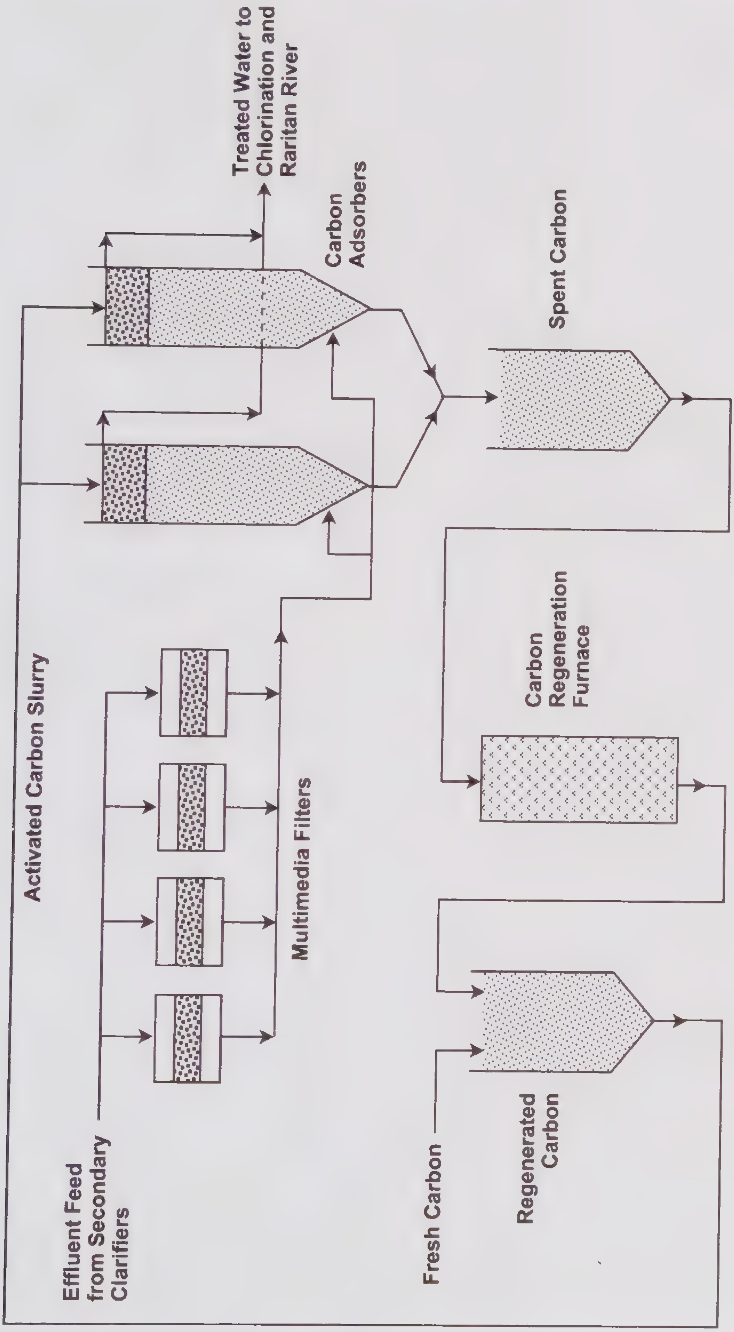
> The pharmaceutical shop at Bound Brook is an important source of basic ingredients for the Lederle Division. At the present time we have few if any alternate sources. You are aware of the fact that we are actively studying the possibility of expanding and upgrading the pharmaceutical shop at Bound Brook. Adequate waste treatment facilities will be an essential part of such an expansion. While it is true that we are also considering alternate sites for the expansion, preliminary economics clearly indicate that we are not able to justify relocation of such facilities. Furthermore, it is clear that the sulfa [drug] manufacturing facilities—the major source of pollution from the pharmaceutical job shop—will remain at Bound Brook.[8]

C. E. Austin, from the Agricultural Division at Princeton, added his approval for the proposed installation based on the draft prospectus. The cost impact to the Agricultural Division in 1974 was significant and concentrated mainly in two products, one of which was the important cattle sulfa drug sulfamethazine: "We have concluded that we should not depend on purchased sulfamethazine from what has been a very volatile merchant market in both supply and price."[9]

A new impetus to the use of best available technology (BAT) was the EPA shift toward greater reliance upon technological controls, rather than health standards, following a 1976 suit brought against the



Flow diagram for primary, secondary, and tertiary liquid-waste treatment, American Cyanamid, Bound Brook



Advanced wastewater treatment plant, American Cyanamid, Bound Brook, 1977 agency by the National Resources Defense Council. This served to enhance interest in activated-carbon treatment of industrial wastewaters. Progress on the Bound Brook carbon treatment plant was recorded in *Chemical Week* under the heading: "Activated Carbon Put to the Test. Lack of Data Posed Problems for Designers of Cyanamid's Huge New Tertiary Waste Treatment Plant in Bound Brook, N.J." Readers were informed that the tertiary treatment plant

will be the largest industrial unit using activated carbon to purify waste waters. And the very size of the unit has made things difficult for the designers and equipment suppliers ... Moreover, the plant is being installed under pressure of a state consent decree ... And one of the designers adds that the design of furnaces to regenerate activated carbon, the key to the economics of the adsorption system, heretofore has been done "by the seat of the pants" ... Cyanamid's remedy for these deficiencies has been extensive testing, which has helped give designers a better fix on solutions.[10]

The article emphasized that the most critical aspect in implementing the AWWT process was the cost of activated carbon—determined in considerable part by the extent to which it was lost during the regeneration. The economics relied almost entirely on the efficient recovery, and reuse, of the granulated carbon.

Municipal and industrial waste treatment managers have shown interest in activated-carbon methods as a way of meeting 1977 and 1983 water pollution control standards. But with activated carbon selling for 50c/lb. they have been taking a close look at how well the system performs ... The Cyanamid tertiary treatment unit, due on stream in July 1977, will be a good test. Each of the 10 treatment columns in the unit will contain 157,000 lbs. of activated carbon. The unit's multiple-hearth regeneration furnace—largest in the world—will return 122,000–152,000 lbs./day of carbon to the system. However, Cyanamid will have to add about 8,400 lbs./day of activated carbon to the system to make up for losses. Total estimated operating costs for the system: $5 million/year ... Anton Marek, who is chief sanitary engineer at Cyanamid's Bound Brook plant, has spent the past five years guiding the activated-carbon unit through pilot operation, testing and design and into construction ... Marek says activated-carbon system is "not an exact science." But he notes that operation of a 30-in.-diameter, 35-ft.-high pilot column has helped show the way.

Donald Kemp, laboratory manager for Metcalf & Eddy (Boston), had designed the system based on a minimum-cost standard, using a reduced flow rate and with regeneration of the carbon at a fixed rate. Richard Delgado, supervising engineer with the NJDEP, "says his agency is taking a wait-and-see attitude: 'Cyanamid has made the best effort it can, but its waste stream is so complex and infinitely variable, it is hard to be sure there won't be some pitfalls.'"

Most plants of this type used air systems for carbon transport. However, according to Marek, "such systems lack velocity control, resulting in carbon losses." In the ten Cyanamid pulsed-bed adsorption towers the filtered wastewater was forced upward through the moving bed, and out through a pipe at the top. Spent carbon was removed from the bottom of the adsorber, and fresh carbon added at the top. The flow rate of the carbon slurry in this countercurrent system was maintained at three to five feet per second. "Eight inlet nozzles in the 45-degree cone at the base of each column will introduce wastewater that has been treated by a mixed-media filter to remove suspended solids ... A Nichols–Herreshoff multiple-hearth incinerator, from Nichols Engineering and Research (Belle Mead, N.J.) will regenerate the carbon." Certainly, American Cyanamid was engaged in a risky operation:

> "There is no single simple answer to reactivation of various carbons with various adsorbates," notes Nichol's Charles von Dreusche, Jr. ... For Cyanamid, installing the new activated-carbon system has been an expensive education in treatment plant design. But the effort may be worthwhile if it puts more scientific accuracy into the design of tertiary treatment facilities, which many chemical companies will require to meet water-quality standards.

The tertiary treatment plant at Bound Brook, located on 22 acres to the west of the American Cyanamid property, began partial operation in July 1977, and full operation in December of that year. It was the largest activated-carbon wastewater-treatment system of its kind. The associated 25 ft.-long carbon regeneration furnace was 8 feet in height. In September 1977, another new waste-treatment plant that incorporated activated carbon, but in this case powder added to the sludge, was inaugurated at the Toms River Chemical Corporation. This was based on the DuPont Powdered Activated Carbon Treatment (PACT) system. The outlay was $15.5 million, with an estimated annual operating cost of $4.5 million.[11] Bound Brook had found this process less satisfactory, particularly in view of the high loss of activated carbon. By 1978, however, the annual cost of operating the Bound Brook plant was $9 million.

The Fate of the AWWT Plant

Despite the overwhelming support given to Loper by the various American Cyanamid divisions for construction of the AWWT plant, the novel waste-treatment process proved incapable of saving Bound Brook. The costly failures of Tobias acid and nigrosine modernization, as described by Isaiah Von, and business decisions concerning the future direction of the corporation, were the major contributors to the demise of the facility. The high running costs and technical difficulties encountered with the AWWT plant certainly did not help. On April 12, 1978, William S. Beggs, of the NJDEP laboratories, advised William B. Honachefsky, manager, Raritan–Interstate Basin, of difficulties with the multimedia filter of the AWWT plant. Hardly surprising for such a pioneering effort, various mechanical problems were encountered, the regeneration unit suffered from pipe corrosion, it was not possible to establish how much carbon was lost, and not all color was removed. Despite the technical achievement of the AWWT plant, on July 31, 1980, American Cyanamid was subjected to further court-imposed restrictions regarding the color and toxicity of its liquid releases.[12] Once the rundown of the Bound Brook facility was underway there was probably little incentive to bring about improvements in the AWWT plant.

For four decades prior to the opening of the AWWT plant, American Cyanamid had widely publicized its efforts in waste treatment and collaboration with local authorities. After 1978, when Anton Marek and Environmental Department engineer Michael A. Pikulin presented a paper on the Bound Brook tertiary-treatment system at the annual Purdue Industrial Waste Conference, little more was heard—in public at least—about the activated carbon system.[13] In 1979, Marek's work as chief of Sanitary Engineering came to an end, and the Environmental Department, consisting of a staff of around fourteen, was cut back. By then only Sid Frankel, who had joined Bound Brook in the early 1950s, and worked with the pharmaceutical and other departments, and two assistants were in charge of environmental affairs.

After dye and pigment manufacture ceased during 1980–82, Cyanamid was unable to sell the Bound Brook colorant-making facilities as a viable concern. The few operations that remained were for the benefit of Lederle. Bound Brook was now known as Bridgewater Lederle Laboratories. With little effective production, arrangements began in 1984 for sale of the AWWT plant to the adjacent Somerset-Raritan Valley Sewerage Authority (SRVSA) publicly owned treatment works (POTW) at a cost of $4 million. In December 1984, American Cyanamid entered into an administrative consent order with the NJDEP and SRVSA. This dealt with compliances according to conditions laid down by the Environmental Cleanup Responsibility Act.[14] The sale of the AWWT was completed in 1985, from which time American Cyanamid sent its secondary effluent, at the rate of 2 to 3 million gallons a day, to the POTW. American Cyanamid entered into a further administrative consent order with the NJDEP in May 1988.[15] In 2000, the New Jersey Public Interest Research Group could report that "[s]ignificant improvements in the Raritan River at Bound Brook were observed at the beginning of the 1980s and are attributed to the gradual reduction in discharge flows from the American Cyanamid facility. In 1985 the company's discharge had been eliminated with flows being transferred to the Somerset-Raritan Valley SA treatment plant."[16]

Chapter 15

The Waste Lagoons, and Groundwater Studies

"During the company's more than 50 years of operation here, an unknown quantity of chemical wastes were buried at the site. The company uses unlined lagoons for treatment and storage of wastewater and sludges. Sludge lagoons were allowed to reach their capacity and were then covered. An incinerator was put into operation in 1979 for the disposal of newly produced sludge ... The lagoons are a potential source of ground- and surface-water contamination due to percolation and mixing with storm water. The groundwater beneath the site is severely contaminated with organic chemicals. The potential spread of contamination into nearby wells and surface water is of concern. The Elizabethtown water supply intake is within 2,000 ft. of American Cyanamid's settling lagoon. There are also at least 20 private wells in the immediate area. Groundwater here is part of the Brunswick aquifer and is the state's second largest source of drinking water."—Robert A. Tucker, "Problems Dealing with Petroleum Contaminated Soils: A New Jersey Perspective," in *Petroleum Contaminated Soils: Remediation Techniques, Environmental Fate, and Risk Assessment*, ed. Paul T. Kostecki and Edward J. Calabrese (Chelsea, Mich.: Lewis Publishers, 1989), vol. 1, 37–53, on 52–3.

Quite apart from liquid wastes and odors, the sludges generated at Bound Brook received attention from early on. Efforts were made to prevent various sludges from escaping and depositing along the banks of the Raritan River. Land to the immediate west of the factory was used in the 1930s and early 1940s for stockpiling iron-oxide sludge from aniline manufacture, as well as other sludges, in settling basins. Once dried, the sludges were removed and stored in piles and in dry basins on wasteland. Some spent iron left the site by rail and was recovered in ironworks. From the late 1940s to the early 1970s, copper sludge from methyl violet production was also stockpiled in the west area, and periodically hauled offsite in railroad gondolas. A chrome sludge from the manufacture of various basic (triphenylmethane) dyes was collected in a waste basin. Waste cake from hydrochloric acid manufacture was made into a stable solid and also kept out of the river. Still bottoms, or sludges, from light oil distillations were originally burned in pits several miles distant from the river. Later these tar sludges were stored in impoundments, particularly nos. 1 and 2, on Calco land between the Lehigh Valley Railroad tracks and the Raritan River.

By the mid-1970s the problem of disposal of accumulated activated sludge from the secondary wastewater-treatment system—material that could not be recovered or reused—required urgent attention. The solution was complete destruction of the secondary sludge, new and old, by burning in the new incinerator, installed at the end of the 1970s. On June 19, 1981, American Cyanamid was served with an administrative order by the New Jersey Department of Environmental Protection (NJDEP), Division of Water Resources, that addressed the need to prevent percolation of contaminants into groundwater from the lagoons and sewers. The accompanying documentation presented yet another historical summary. It was stated that: Over 800,000 tons of wastes had been discharged into 21 to 27 lagoons ("including Hazardous materials"); lagoons 6 and 7, part of the primary waste-treatment plant that operated under a permit of March 6, 1957, "do not conform to current practice and procedure of the NJDEP under the Water Pollution Control Act"; the stipulation and consent judgment entered into on October 12, 1973 required American Cyanamid to "study alternative methods to eliminate its on-site treatment lagoons or protect those lagoons from infiltrating during floods and eliminate groundwater contamination by sludges/wastes in the lagoons"; and the Superior Court of New Jersey, Chancery Division, in an amended consent judgment of November 15, 1975, "did not modify terms concerning Cyanamid's required studies of the on-site lagoons, or the intrusion of wastes into the groundwater."

American Cyanamid engaged a number of engineering consultancy firms to undertake surveys of the lagoons and of the impacts of their contents on surrounding soil and groundwater, and to make recommendations for improved storage conditions. These included Arthur D. Little, Inc., commissioned to investigate lagoon contents, and environmental engineers Geraghty & Miller, commissioned to undertake leachate analysis.[1]

This chapter takes a more detailed look at: how, following the 1973 consent judgment, the NJDEP and American Cyanamid approached the interconnections between the lagoons and groundwater at Bound Brook during 1976–82; the response of the local community to cleanup programs and waste issues; and more recent progress in treatment of soil and groundwater.

Surveys of Lagoons and Leachate into Groundwater at Bound Brook

The 1973 consent judgment that made necessary studies of methods for eliminating any intrusion of the contents of on-site lagoons into groundwater had stemmed in part from observations by NJDEP personnel of dark liquid on ground adjacent to the two light-oil sludge lagoons, nos. 1 and 2. In 1935, Bound Brook began processing light oil obtained from the distillation of coal tar produced in the steel industry. Prior to distillation, for isolation of benzene, toluene, xylene, and naphtha solvent, it was necessary to remove olefins by washing with sulfuric acid and, later, thiophenes by treatment with formaldehyde. This generated an acid sludge which with the residue from distillation of the light oil was placed in the two lagoons, excavated after World War II. The light-oil operations were discontinued in the 1960s. By then the two lagoons contained several million gallons of sludge.

In April 1977, William Honachefsky, manager, Raritan–Interstate Basin, asked Bound Brook management for a progress report on the groundwater studies.[2] In the following month American Cyanamid directed Geraghty & Miller to undertake leachate analysis of various organic compounds in groundwater close to the light-oil sludge lagoons.[3] This involved chemical analysis of subsurface and well water in the parts per million range. Such measurements had been achieved in the late 1950s by Bound Brook chemists, who were among the first to apply chemical instrumentation, particularly UV spectroscopy, to analysis of low levels of aromatic contaminants in well water. By the 1970s, newer instrumental technologies, using elaborate sensors, and sensitive detection equipment, enabled rapid, routine measurements of contaminants at low parts per million.[4] The analyses of samples by gas chromatography, as reported by Geraghty & Miller, revealed the presence of heavy and volatile organics, including phenol, in the subsurface water throughout the area occupied by the facility. The system of numbering of lagoons adopted by Geraghty & Miller in its reports was subsequently retained by all parties engaged in investigations and remediation activities, including the EPA.

Richard Bellis of the NJDEP took up the matter of groundwater pollution with the Organic Chemicals Division's president, Ben Loper:

> We are concerned about unlined lagoons used by the Company for treatment and storage of wastewater and sludges. These lagoons are a potential source of groundwater and stream pollution due to percolation and due to mixing with flood water in time of storms. We are also somewhat concerned that dredging activities in the settling basin [no. 7] may result in increased rate of leakage of the lagoon's contents to the groundwater.[5]

The concern over groundwater contamination, and American Cyanamid's apparent delay in complying with the terms and conditions of the 1973 stipulation and consent judgment, led the NJDEP to request an administrative hearing.[6] Early in 1978, the corporation's failure to submit studies of groundwater contamination, and proposals for eliminating the onsite treatment lagoons and preventing groundwater contamination from lagoons, was referred to the Superior Court of New Jersey, Chancery Division, Somerset County.[7]

The EPA also became involved in the pursuit of American Cyanamid. In February 1978, EPA director Meyer Scolnick received a request from the NJDEP's Richard Bellis that the agencies share information.[8] Following the hearing before the Superior Court, on April 11, 1978, American Cyanamid was ordered to submit the results of certain studies called for in the 1973 consent judgment on or before May 10, 1978.[9] New Jersey deputy attorney general Peter Herzberg observed: "Needless to say, this Order is a culmination of a two and one half year effort by many people to overcome enforcement problems caused by the 1973 Consent Judgment between the State and Cyanamid. I appreciate everyone's help in that effort. Now we can go on to begin prosecution in both State and Federal forums so that many of the outstanding pollution problems at Cyanamid's Bound Brook facility can be corrected."[10]

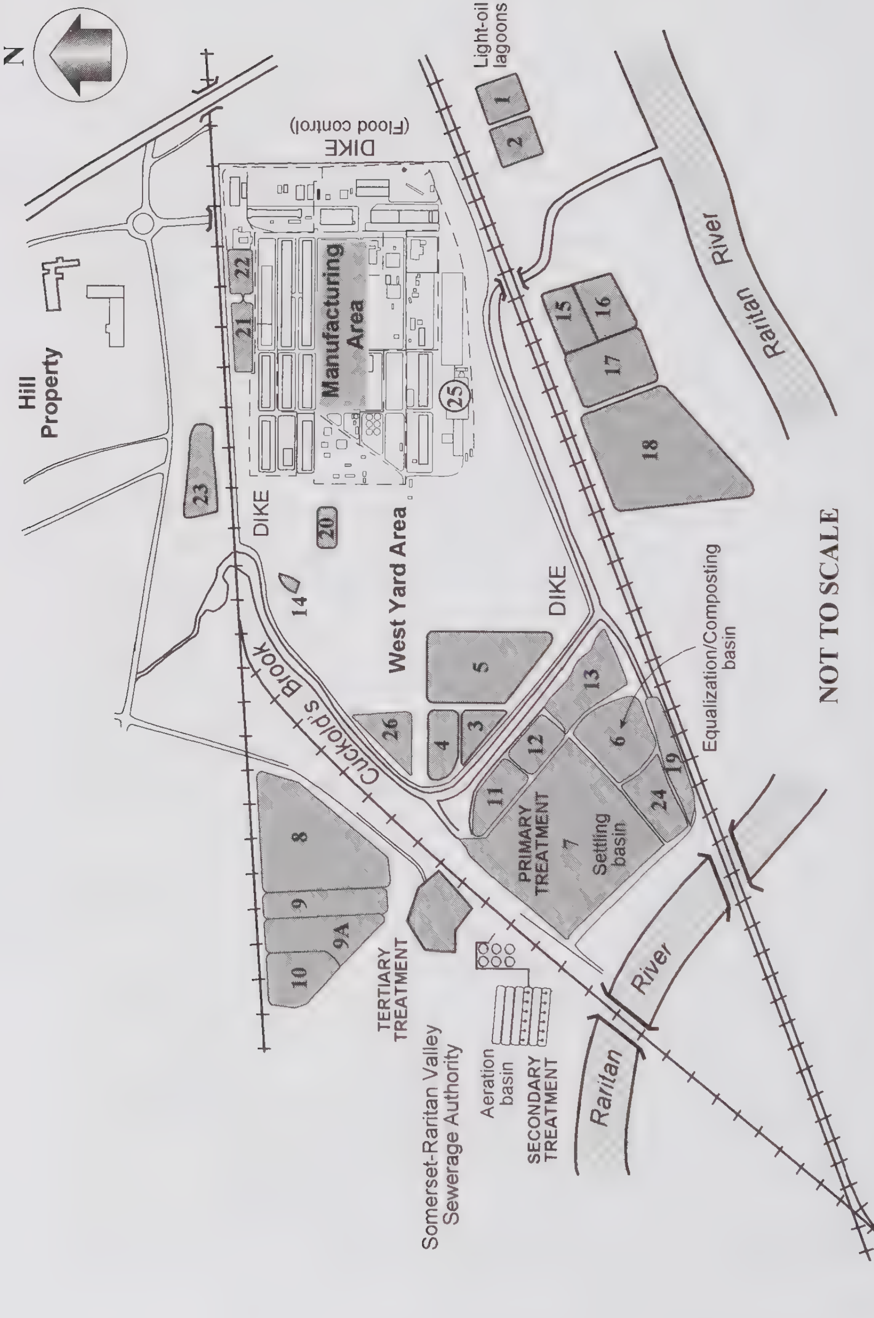
On May 1, 1978, Honachefsky received a report on one of the light oil lagoons from William S. Beggs, of the NJDEP laboratories. "Although the lagoon is supposedly lined with clay, there is concern that some of these materials might seep into the groundwater. Evidently," Beggs opined, "Cyanamid is more interested in studying the problem than solving it." Beggs had visited Bound Brook on April 7 with a colleague, Edward Stevenson, and taken a sample of wastewater during partial bypassing of the advanced wastewater treatment (AWWT) plant. He noted a strong odor of nitrobenzene, one of the refractories that should have been removed during tertiary treatment.[11]

On May 9, Cyanamid submitted its report on groundwater to the NJDEP. The next day, Bound Brook plant manager Eldon Knape reported that "increased concentrations of toxic and hazardous pollutants including benzene, trichloroethylene, chloroform, dichloroethane and tetrachloroethylene, trans-1,2-dichloroethylene, 1,1-dichloroethane, aniline, naphthalene, and acenaphthylene reached groundwater from Cyanamid's storage lagoons, sewer system, collection sumps and from chemical spills." However, "they did not migrate off-site." Not convinced by the assertion that any contamination was contained by withdrawal through the facility's production wells, Herzberg, on June 22, requested that Stevenson draw up a list of groundwater studies and abatement measures "which we feel [American Cyanamid Company] should be required to undertake."[12] On July 5, Knape was advised by Herzberg that the state required additional information, including data on geology and the wells at Bound Brook, if American Cyanamid was to meet the requirement of the 1973 consent judgment. Moreover, the NJDEP demanded from American Cyanamid a comprehensive report supporting the claim that through pumping of production wells the contamination did not reach the groundwater within the Brunswick Shales. This included provision of supporting documentation dealing with the condition, location, and accessibility, of abandoned production wells, "including dates of abandonment and analyses showing the degree of contamination," and analysis of contamination levels ("including organic chemicals within the aquifer in said defined area"). Information on chemical spillage control measures was required in the form of a "report on the containment and control measures for routine spillages from chemical transfer operations and storage," to include contamination of groundwaters due to "seepage through paved and/or unpaved areas and exfiltration from the collection system." Finally there was the warning that if the background data and reports were not adequately or properly undertaken, and delivered by the second week of July, then the NJDEP would institute legal action.[13]

On July 27, Knape informed Herzberg that American Cyanamid would provide construction information concerning the lagoons by the end of October. "We do not believe at this time that it will be necessary to drill additional wells or borings. Nor do we believe that the extensive effort to determine the integrity and the extent and direction of migration for each lagoon will be productive ... the matter is not a problem limited to one or a few treatment lagoons." Knape emphasized that "[a]s pointed out in our report of May 9, 1978, we believe that any intrusion into the Brunswick Aquifer is being contained and removed by our onsite production wells."[14]

Herzberg's concern arose from the fact that the water table at the facility was close to the surface, and many wells were already closed due to contamination. Below was the Brunswick Aquifer, New Jersey's second largest source of drinking water. The NJDEP demanded to know if the 35 shallow wells and three deep wells could yield sufficient data to enable correction of Bound Brook's leachate problem, in addition to requiring a proposal from Geraghty & Miller. Additionally, it was requested that the data and chemical analyses be submitted by the end of August. "A contour map is necessary to achieve a total picture of the flow of the known contaminants in the groundwater. Furthermore, without the Geraghty & Miller proposal, it is difficult for the State to even understand the company's 'program.'"[15] The Geraghty & Miller groundwater study was made available on October 1, 1978, followed by revised information in mid-October.[16]

In June 1981, American Cyanamid was served with an admin-



Location of liquid waste treatment facilities, lagoons, and impoundments, American Cyanamid, Bound Brook

istrative order by the NJDEP Division of Water Resources, based in part on Geraghty & Miller reports. The latter "indicate that discharges resulting from Cyanamid's operations, including the usage of lagoons, the leaking sewer systems and chemical spillages ... seriously contaminate the aquifers beneath the facility with hazardous chemicals." Though American Cyanamid claimed that contamination was contained on-site by continuous pumping of its process wells, "[t]he age and large size of Cyanamid's facility, the nature of the underlying aquifers, and the limited number of monitoring wells providing data upon which the conclusions contained in the Geraghty & Miller reports are based, precludes demonstrating that historically, presently or in the future all groundwater contamination can be or has been controlled and confined to the property." American Cyanamid was instructed to submit to the NJDEP within forty-five days of receipt of the order a sampling program designed to assess the effect of discharges to groundwater on the quality of the area's surface waters, including the Raritan River, and a detailed engineering plan designed to accomplish the elimination of discharge of pollutants which may flow or drain into the groundwaters of the state.

Also required was a plan "designed to accomplish an assessment of specific effects on groundwater quality resulting from each individual discharge," containing recommendations for appropriate remedial measures "for each such discharge, in order to eliminate the degradation of groundwater quality, either on or off-site." The sources of pollutant discharges to be addressed were lagoons (including waste impoundments, wastewater treatment lagoons, and wastewater collection sumps), sewer systems, chemical storage facilities, and chemical spillages. American Cyanamid was ordered to check for chemical indicators of its activities: "[A]t a minimum, the installation of additional groundwater monitoring wells, and additional groundwater sampling, may be necessary to adequately assess the specific effects of each individual discharge ... After NJDEP approves the engineering plan, an application for an NJDEP permit for certain discharges may be required ... Cyanamid must collect annual samples from selected overburden monitoring wells within the lagoon area to document improvements in shallow groundwater quality and submit results to NJDEP." Moreover, "Cyanamid must continue to maintain groundwater withdrawal at the facility at a rate sufficient to mitigate the migration of existing known contaminants off the Cyanamid property." An important remedial measure concerned the treatment of groundwater "pumped from the bedrock aquifer" that was required to be "treated by Cyanamid's advanced wastewater treatment system prior to discharge into the waters of the State."

American Cyanamid was required to submit within forty-five days of the order a comprehensive report to Joseph M. Mikulka, chief, Region IV, Enforcement and Regulatory Services Element, Division of Water Resources, NJDEP, at Trenton, specifying the steps taken to prevent off-site migration of contaminated groundwater and contamination within the facility. Quarterly operator's reports were also required that documented: pumping; disruption to pumping; water level measurement in 7 bedrock monitoring wells; and sampling analysis of 3 production wells, 2 private wells, and the 7 bedrock monitoring wells. The NJDEP was authorized to assess a "Civil Administration penalty of up to $5,000.00 for each violation, and additional penalties of $500.00 for each day during the time which such violation continues." Attached to the order was a list indicating, as far as could be ascertained, the operating dates for the 26 lagoons and basins at Bound Brook:

1 1956. Abandoned 1965. Majority of sludge removed under contract 1966–67.
2 1947–56.
3 1933–75.
4 1933–75.
5 1950–75.
6 1940. Active. Primary treatment equalization/composting basin.
7 1940. Active. Primary treatment sludge settling basin.
8 1969. Active. Primary treatment sludge storage basin.
9 1958. Never used.
9A 1958–69. Primary and secondary sludges.
10 1958. Never used.
11 1940–50. Primary sludge, furnace ash, and clinkers.
12 1940. Never used.
13 1940–59. Lime storage.
14 1954–58.
15 and 16. 1943–65. Iron oxide sludge.
17 1966–69.

18 1950–65.
19 1940–59. Lime storage.
20 1955. Active. Pretreatment basin for effluent from dyes processes. Contained sludge from basic dye processes.
21 1939. Active. River water reservoir.
22 1932. Active. River water reservoir.
23 1947. Active.
24 1940–59. Lime storage for neutralization.
25 1939. Active. Plant effluent collection basin.
26 1933–55.

Estimates of lagoon contents included: Lagoon 3, 23,000 tons; lagoon 4, 34,000 tons; lagoon 5, 135,000 tons; lagoon 18, 230,000 tons; lagoon 19, 17,000 tons; lagoon 20, 8,000 tons; lagoon 26, 15,000 tons.

In December 1981, American Cyanamid entered into an administrative consent order that became effective on January 1, 1982. The last open ditches were replaced with pipes. A pump-and-treat system to ensure that groundwater contamination below the main plant and west yard area was contained, and remediated, was installed. The NJDEP ordered American Cyanamid to remove the contents of lagoons 1 and 2, those containing sludges and residues from distillation of tars, by December 31, 1986. During April 1982 to February 1983, American Cyanamid's consultant O'Brien & Gere undertook investigations that led to a "Lagoon Characterization" report. The conclusion was that: four lagoons, numbers 3, 5, 9A, and 14, had "probable" impact on groundwater; lagoons 3, 5, and 14 contained MBT/MBTS (lagoon 14 also contained byproducts of naphthalene processes); and lagoons 3 and 5 contained waste from beta-naphthol manufacture. Four lagoons, 4, 6, 20, and 26, had "uncertain" impact (lagoons 4 and 26 contained MBT/MBTS). Finally six lagoons, 7, 13, 17, 18, 19, and 24, had "doubtful" impact on ground water.[17]

Hazardous Waste: American Cyanamid Confronts Concerned Citizens and Environmental Activists

In an earlier era, before the mid-20th century, chemical industry was the prize of corporate America and the darling of Wall Street and insurance companies. States and townships were proud of the branches of chemical industry that gave employment to thousands of their residents, paid taxes, and enabled communities to flourish. Calco in the 1930s enriched Somerset County "by bringing money from all over the world to be distributed in wages, salaries and dividends." The industry, in turn, often used its economic and political muscle to hold sway over certain local affairs, including in matters of effluent disposal. The same thing had happened with the dye and other industries of Germany and England around 1900.

From the early 1960s, however, there was a complete change. Different concerns drove government, economic, and public sentiments and altered the media's perspective. As industrial facilities declined in size, employing a few hundred people rather than several thousand, economic benefits for, and cordial relations with, communities also declined. More than ever before, it became incumbent on industrial concerns to learn to take responsibilities for their actions in the environmental arena, the politics of which dominated much of the last decades of the 20th century in the United States. Chemical industry, and its waste handling and disposal histories, came under unprecedented scrutiny.[18]

As industry fought to restore its integrity, it was faced with sometimes hostile public sentiment, and not a little cynicism. For American Cyanamid, this reached a peak around 1990. What the corporation confronted was typical of responses elsewhere in the United States. Some charges were made in bad faith; others served to highlight misunderstandings; many were based on justifiable concerns and fears. This section outlines how heightened public consciousness toward environmental issues impacted on the former Bound Brook dye-making facility, including the—again not untypical—ways in which federal, state, and local bodies handled approaches to cleanup of soil and groundwater.

Local action followed an American Cyanamid announcement in July 1987 that it had submitted a proposal to the NJDEP for construction of a toxic-waste incinerator at the southwest corner of what was now known as its Bridgewater facility. This spurred Bridgewater residents to found CRISIS (Concerned Residents Involved with Stopping Incinerators). In November 1988, and June and December 1989, CRISIS, Inc., and Bridgewater community and civic leaders were "successful in preventing attempts by the state Legislature to allow Cyanamid to be considered for a hazardous waste incinerator."[19] The community's watchdog groups during the following years were CRISIS and Bound Brook Citizens Association, invariably backed up by Bridgewater's mayor, James T. Dowden, who publicly embraced activists in criticizing both American Cyanamid and state authorities.

Bridgewater citizens, other local people, and public officials held several meetings to review what was happening at the American Cyanamid site. Thus, in January 1989, they discussed remedial work under a 1988 administrative consent order, and inauguration of a remedial investigation/feasibility study (RI/FS study) overseen by the NJDEP. This was followed with a public meeting on February 21, at which citizens expressed considerable confusion about cleanup steps. The environmental consultant Blasland, Bouck & Lee began work on the RI/FS study later in the year. Lagoons and basins were classified into three groups of impoundments: Group I impoundments—11, 13, 19, and 24; Group II impoundments—6 and 17; and Group III impoundments—1, 2, 3, 4, 5, 14, 20, and 26.[20] The Hill Property also came under scrutiny.

In the spring of 1990, American Cyanamid became the focus of highly organized environmental activists from further afield, when the destination of spent mercury catalyst used since 1963 in the manufacture of Cyanacryl elastomers at Bound Brook was turned into a new issue. From 1986 this waste was shipped to South Africa for recycling at Thor Chemicals, Inc., SA Ltd, a British-owned reprocessing plant situated outside the KwaZulu-Natal homeland. However, in March 1990 reports of mercury poisoning of Thor employees emerged. Thor was found responsible for river water contamination and its plant was temporarily shut down. The Greenpeace organization released a statement declaring that prevention of the Thor and similar tragedies could be brought about only by making the international waste trade a global crime. This multiplied the occasions for confrontations.[21]

The May–June 1990 edition of *Greenpeace Magazine* reported that American Cyanamid and Thor "were the target of demonstrations by Greenpeace, local and national environmental groups, trade unions, and anti-apartheid groups." The first demonstration, on

April 14, was at the Bound Brook facility (Bridgewater Lederle Laboratories), where 300 protesters were confronted by 75 police in riot gear. In June, plant manager C. S. Forsyth responded to what were considered to be hostile comments aimed at American Cyanamid from the mayor of Bridgewater in the *Courier–News*:

Regarding Bridgewater Mayor (James) Dowden's recent letter to the editor, if there is a victim of the April 14 demonstration at the Cyanamid Plant in Bound Brook, it is the local residents. I believe well-meaning residents with a legitimate interest in Cyanamid's activities have been manipulated by an international environmental activist organization through deliberate distortion of the facts.

In earlier newspaper accounts and in his letter to the editor, Dowden claims that Cyanamid hides behind a shroud of secrecy, that he knew that mercury was at our Bound Brook facility, and that Cyanamid is not concerned about the environment or the plant's neighbors.

Forsyth emphasized that American Cyanamid staff had worked closely with various local interests. The corporation's manager of Environmental Affairs, Ray Hillard, and the environmental project manager, Joel Jerome, had made public presentations to "residents and public officials about the ongoing cleanup program at the site to which Cyanamid has dedicated $84 million." The manager of Environmental and Safety Services at the facility, Douglas Bondor, chaired the Somerset County Hazardous Materials Advisory Council, "an organization of industrial and public sector emergency management representatives." Karel Bernady, plant manager in the 1980s, and Anton Marek, manager of Commercial Environmental Services, who had worked on the advanced wastewater-treatment plant in the 1970s, had "established a Citizens Advisory Council for the community to learn more about our proposed hazardous waste incinerator project." According to Forsyth, mayor Dowden had "rejected any participation by Bridgewater officials and encouraged residents to avoid associations with our Citizens Advisory Council."[22] (From 1991, the facility's waste mercury was handled by Chemical Waste Management Inc., of Illinois, and disposed of in a landfill, "an acceptable practice, regulated and permitted by the U.S. Environmental Protection Agency.")

On June 7, the same day that Forsyth's views were published, the

EPA released its first civil administration complaint for violations of the Toxic Substances Control Act, Section 5, and its Toxic Releases Inventory and Site Enforcement Tracking System, that provided extensive nationwide data on contaminated sites. The Site Enforcement Tracking System identified American Cyanamid as a potentially responsible party (PRP) at thirty-three Superfund sites, the seventh highest in the chemical industry by number of sites. Bound Brook was stated to be 126th in the league of worst contaminated sites in the United States, and the 26th worst site in New Jersey. In 1991, the New York-based Council on Economic Priorities (CEP) noted in its corporate environment record: "The company's Form 10-K report to the Securities and Exchange Commission reported in 1988 that American Cyanamid entered into an administrative consent order with the State of New Jersey, Department of Environmental Protection, concerning remediation [at Bridgewater] … which required a $39 million letter of credit to secure Cyanamid's obligations under the consent order… According to the EPA's 1988 Toxics Release Inventory, this facility reported the release of 145,842 pounds of toxic chemicals to the environment. Bridgewater is the location of an American Cyanamid Superfund site. The company agreed to clean up the Bridgewater site with $84 million, the largest contribution for the clean up."[23]

In March 1991, CRISIS, whose activities now went far beyond objecting to the incinerator, voiced concern over an amendment to a hazardous waste facility permit that would enable storage and blending of tars from lagoons 4 and 5. Bridgewater mayor Dowden and council president Donaldson, concerned that the state authorities were not acting in the best interest of the township, promised to give citizens comprehensive and prompt access to information available on the site cleanup.[24] In 1992, the EPA, under the Superfund program, provided CRISIS with a Technical Assistance Grant to hire a consultant for review of documents and evaluation of remediation work. Further concerns were expressed at a meeting held on August 4 as to contamination of Cuckold's Brook and the extent to which American Cyanamid's pumping operations were controlling groundwater pollution and preventing contaminated water from moving offsite. In March 1993, CRISIS announced that American Cyanamid had, in the previous December, filed a petition with the EPA requesting removal of Bridgewater (Bound Brook) from the Superfund National Priorities List (NPL). On April 16, members of CRISIS accompanied congressman Robert Franks, local officials, and representatives of the New Jersey Department of Environmental Protection and Energy (NJDEPE) and the EPA on a site inspection.[25]

Following the visit, the NJDEPE and the EPA convened a public meeting and hearing on August 5, 1993 at the Bridgewater Township Municipal Court to discuss proposals for the Group I impoundments.[26] On August 24 a working meeting between the NJDEPE, CRISIS, and representatives of Bridgewater Township addressed several outstanding issues concerning the impoundments. In September, a Superfund Record of Decision was passed for the Group I impoundments; the *Courier–News* announced that state and federal authorities had "formally approved a partial $12.5 million cleanup project at the American Cyanamid Superfund site."[27] Extensive surveys of the various impoundments and lagoons, including corrective measure and feasibility studies, remediation reports, and evaluation of treatment processes, were continued throughout the 1990s.[28]

Remediation work at the site included: installation of triple liners in lagoons; operation of a leachate detection and collection system; monitoring for sixteen lagoons that contributed to groundwater contamination; recycling off-site of iron oxide from the reduction processes; and solidification and consolidation of certain wastes. Severe flooding in September 1999 was contained by the dikes and berms and did not lead to further spread of contamination.[29] By that time American Cyanamid had spent $90 million on remediation, and was scheduled to spend a further $75 million over the next nine years. The American Cyanamid Bridgewater facility remains on the NPL mainly because it is situated adjacent to the Raritan River and above the Brunswick Aquifer. Moreover, within a three-mile radius there are approximately 14,000 residents. The closest home is two thousand feet away, and there are 30 private wells near the site.[30]

In the 1980s and 1990s, numerous industrial corporations claimed pollution-related cleanup and remediation costs from their insurance companies, using the argument that so-called occurrence-worded policies, issued until the 1970s, did not contain pollution restrictions. The occurrence-worded format covered a fixed period, generally one year, but, unlike claims-made policies, placed no restrictions on when a claim could be lodged for that period. Thus, it was argued, they did not exclude gradual, or "historic," damage. Claims for cleanup of historic contamination were settled only following lengthy litigation, with varying interpretations of pollution-exclusion clauses, polemics over what polluters knew or should have known about their activities (which affected whether or not cover was applicable), and, if cases reached the court, no general consistency in decisions.

American Cyanamid pursued claims against its insurance carriers for pollution-related costs during the 1990s. Comprehensive settlement was reached by mid-February 2000, when "dozens of American Cyanamid's general liability insurers agreed to pay 'about $200 million' to help remediate 21 contaminated sites nationwide (including 10 in New Jersey). Cleanup costs at these 21 sites will total at least $520 million."[31] At Bound Brook, final site-wide groundwater remediation will follow soil remediation, scheduled to start after all impoundment work is completed, currently planned for 2008, almost a century after Calco began making dyes in America.[32]

The 140-acre Hill Property, deleted from the NPL on December 29, 1998, is now covered with a retail mall. Closer to the railroad, on what was once the Calco parking lot, is a ballpark. On April 13, 2002, the newly renovated Van Horne House, owned by the Heritage Trail Association, opened its doors to the public on the 225th anniversary of the Battle of Bound Brook.[33]

Chapter 16

Conclusion to Part 2

Perceptions of the synthetic dye industry have changed. Less than a century ago it was a field rich, almost breathtaking, in achievement and historical moment, endowed with seemingly endless technological capabilities. As a 1941 collection of Calco accounts informs us, it was about how a "world monopoly had been created by the European chemical industry, particularly by the phenomenally productive and brilliant German chemists ... since Perkin's great discovery, literally thousands of new dyes have flowed from the chemist's laboratory." The same account explained that after 1915 it was also an American success story, particularly—and in many ways exceptionally—at Bound Brook, where "sticky, smelly coal tars are transformed by the magic of chemistry to brilliant dyes."[1]

Today, synthetic dyestuffs, or colorants, are considered to be the outcomes of a mature technology, one that once led the world into the first science-based high-tech industry, but whose main relevance, except to manufacturers and users, is confined to the history books dealing with science and technology in Europe before 1914 and, to a much lesser extent, the United States in the following decades. Calco and its successor divisions under American Cyanamid was certainly the outstanding American example. Bound Brook grew by dint of talent and energy to a pinnacle in the 1940–60 period, and then was brought down by, among other things, new social values and pressures—economic, environmental, and technical.

The purpose of this study has not been to rewrite the history of dye making, particularly in America, but to fill in the details of how a single representative site fared when faced with a variety of challenges, not just of economic ups and downs and technological challenges, but also of "nuisances" that assaulted the environment. Until recently, recording this latter episode has not been easy. As historian Peter J. T. Morris remarked of a history of chemical industry that attempted to cover environmental issues: "One might have hoped that the environmental aspects could have been fully integrated into the historical account. Perhaps, in practice, this is too difficult until a much larger body of environmental history exists."[2] Now we have available the critical mass of scholarly historical and technical studies that makes this possible.[3] They demonstrate, from a historian's perspective, that precedents from one era that lay fallow for decades were "rediscovered" when public attitudes changed, in this case in the 1960s.

There is much published evidence that environmental issues, particularly concerning the relentless contamination of the Raritan River, were taken seriously by American Cyanamid. Nevertheless, despite the corporation's scientific and technical capabilities, inadequate status was given to research into waste-treatment technologies, and there was too often—though not always—a serious lack of communication and collaboration between the company and state authorities.

Both these points were stressed, respectively, by Calco's consultant Sheppard T. Powell in the 1940s (when referring to chemical industry in general) and in the Superior Court of New Jersey during the 1970s. There are remarkably strong parallels with the different attitudes toward research and development among the layers of management, as discussed in Part 1 of this study. Thus, according to the NewYork-based INFORM organization that undertook surveys of waste and waste handling at U.S. chemical firms in 1985 and 1992, "the obstacles to pollution prevention were not regulatory, technological or even economic but predominantly institutional ... [T]he staff of pollution control departments were neither responsible for nor knowledgeable about the plant processes that produced the wastes they had to handle."[4] This again fits neatly into Steven Goldman's model of institution-specific managerial decision making and its inherent problems rooted in past practice, in this case lack of emphasis on environmental considerations.[5]

While there was an underinvestment in waste treatment, this is not to say that American Cyanamid did too little. The hiring of leading waste-treatment consultants and the proliferation of publications say much for the corporation's efforts to come to terms with new and rigid regulations and growing releases into the Raritan River from expanding production. By 1941, Calco had "used more than 75 different men during more than 15 years in the study of river pollution and have spent half a million dollars in trying to reduce, as much as possible, the contamination of the river."[6] Despite the primary treatment plant's contribution toward a reduction in pollution load, the assimilative capacity of the Raritan, particularly in summer months when drought reduced the flow from 90 to 60 million gallons a day—and sometimes considerably less—was inadequate to prevent the water from absorbing color present in releases.

The complexity of the waste grew with diversification into rubber products, pharmaceuticals, and resins. From the 1940s, Bound Brook scientists investigated source reduction and various available waste-treatment technologies in determined efforts to reduce pollution levels and comply with mandated standards. They developed a number of innovations that were notable for both novelty and sheer scales of application. In the 1950s, studies on biological treatability that had started with stationery filters led to the installation of the activated-sludge, or secondary, treatment plant. The important aeration was later improved through additional capacity, to enhance oxidative breakdown of pollutants. The primary and secondary plants were referred to as models of their kind, and inspected admiringly by professionals during the several years after their inaugurations. Moreover, prevention, or elimination, of waste, rather than treatment and disposal, accompanied certain process changes, such as the catalytic reduction of nitrobenzene.

Certainly this was not a case of overly aggressive regulators battling a corporation that failed to keep up-to-date. The tensions that existed were born mainly of different perspectives. Values changed over time, and it was in the 1960s when new guidelines for water classifications and minimum standards were introduced that there was the major dislocation in the tolerance of industrial emissions. Bound Brook's releases to the Raritan River failed to satisfy both state and federal agencies. The requirements for even greater reduction in contaminant levels in wastewater led to the final response—elimination of trace refractory organic chemicals and certain toxic metals with adsorption on activated-carbon, or tertiary treatment. This was also adopted at DuPont and Toms River Chemical (CIBA-Geigy), where a quick-acting batch process, more wasteful in the powdered carbon, was introduced. The process had the advantage that it did not require the installation, and great expense, associated with special adsorption towers filled with granular activated carbon, carbon-regeneration furnaces, and ancillary equipment, as were employed in the continuous process.

With granulated activated-carbon treatment, there was also the prior need for extensive R&D and unusually comprehensive engineering studies, since it had not previously been used in the large-scale treatment of industrial wastewater containing aromatic chemicals. Through investing in the continuous process, the Organic Chemicals Division displayed remarkable confidence in its purpose, and proved to be well ahead of its time. There were certain teething problems after the process came on stream in 1977 and, for as long as dye and pigment manufacture continued (until 1980–82), the treated effluent still displayed some color. However, granulated activated carbon was a move in the right direction.

The continuous advanced wastewater-treatment process represented state of the art and was fully worthy of a technologically advanced industry, certainly far more so than the automated and continuous processes for manufacture of aromatic intermediates that never came up to expectations at Bound Brook and Willow Island. It was the failure of the latter that led to the end of colorant manufacture, which meant that there was less waste to be treated and thus a diminished role for the facility's innovative activated carbon-treatment process. By the year 2000, filtration through packed towers of activated carbon and regeneration of spent carbon was generalized to various industries. It remains ecologically and economically the most desirable process for treatment of industrial wastewaters.

Finally, while a historical tract on the development and impact of the dye industry until the late 20th century has in itself been worthwhile, the story is far from reaching closure. The last decade has witnessed fast-growing and novel applications of some of the very same dyes described here, as well as of new dyes based on existing classes, to a ubiquitous artifact that is connected to the growth of digital technologies, namely the photorealistic ink-jet printer. Both mature and rapidly evolving, this field has become a multibillion-dollar business, driven by information technology and computer products, that itself one day will provide new material and historical context.

APPENDIX

Synthetic Dyestuffs

This appendix is not intended to provide a primer in a mature, some would say arcane, area of industrial chemistry, but a summary of some important processes carried out at Bound Brook. The nomenclature and abbreviations used here and throughout this book are as adopted at Calco.

Dyestuffs form a distinctive, as well as diverse, group of chemical compounds, whose commercial nomenclature is often far from systematic, and harks back to long-forgotten individuals, events, and natural products, as well as to firms such as Calco. Magenta and safranine, for example, are named after military battles. Another name for magenta is fuchsine, from the fuchsia flower. The free salt is rosaniline, and a close relative is *para*-rosaniline. Eosin(e) comes from the name of a lady friend of the inventor, Heinrich Caro; Congo red was discovered in the same year (1884) as a major political agreement among the European powers over a region of Africa; Meldola's blue is named after its discoverer, the British chemist Raphael Meldola; and alizarin, the red dye from the root of the madder plant, derives from the Arabic name, Alizari, of the plant. Alizarin is one of many derivatives of anthraquinone, which include vat dyes such as Jade Green. Manchester brown and Bismarck brown are synonyms for the same colorant, and tell us where it was first introduced, and where it came to prominence. The brown is a dye of the azo class. Magenta, eosin, Congo red, Meldola's blue, Jade Green, and Bismarck brown are all examples of the types of dyes once made at Bound Brook.

Commercial and generic names, as well as a system of numbering that identifies constitutions, are brought together in the *Colour Index*. Each colorant is referred to according to its application, the C.I. Generic Name, of which there are some 8,000, and to its chemical classification, the C.I. Constitution Number. Examples are the following Calco vat dyes: Vat Jade Green, C.I. name Vat Green 1, C.I. no. 59825; and Vat Gray 2G, C.I. name Vat Black 22, C.I. no. 65260.

Early Triphenylmethane Dyes at Bound Brook

The first important commercial "aniline" dyes, dating from the 1860s, were soon found to be derived from both aniline and amino compounds of toluene. They included *para*-rosaniline, as made at Bound Brook, originally by the nitrobenzene oxidation of aromatic amines, a process introduced in the mid-1860s. In the 1960s it was made in the Pigments Department by condensation of amines with formaldehyde in a two-step process that had become available following elucidation of the structure of rosaniline in 1878. The aniline dyes were then shown to be triphenylmethane derivatives, though it is more correct to called them triarylmethane, or triarylmethine, derivatives.

At Bound Brook, the condensation was carried out with an excess of aniline. The product mixture containing *para*-rosaniline and byproducts, following removal of excess aniline by steam stripping, was drowned in water at 30°C and precipitated in the form of hard pellets. The aqueous layer was separated from the pellets containing the product in a filter press, and the pellets were then treated in an extraction tub. The Pigments Department produced around 300,000 lbs. of *para*-rosaniline a year in the early 1960s.

Malachite green is another example of a Calco product belonging to the triphenylmethane dyes. The two most important dye classes during the 20th century, however, were azo and anthraquinone vat dyes, as made at Calco from around 1915, and after 1930, respectively.

Azo Dyes

The intermediates

These are made from compounds such as benzene, alkyl benzenes (toluene and higher homologues), phenol, and naphthalene. A limited number of reactions are used to produce the important dye intermediates, including nitration, reduction, halogenation, sulfonation, *N*-alkylation, *N*-arylation, and alkali fusion. The sulfonic acid derivatives of alpha- and beta-naphthol, and alpha- and beta-naphthylamine, were important coupling components for azo dyes and pigments.

Beta-naphthol is an important intermediate made from naphthalene. Sulfonation of beta-naphthol affords 2-naphthol-1-sulfonic acid, often, as at Calco, known as Armstrong acid (after the English chemist Henry E. Armstrong). Armstrong acid was converted by the Bucherer reaction into Tobias acid, 2-naphthylamine-1-sulfonic acid. This was followed at Bound Brook by a series of purification steps, including precipitating, filtering, redissolving, reprecipitating, and then drying and grinding the product. Sulfonation of beta-naphthol required twelve hours, and the next step, amidation, a further ten hours. The process in use until the 1970s was almost the same as that installed in 1935. Of the 1.5 million lbs. made each year, some 70 percent was sold to other manufacturers. Tobias acid was used in the preparation of pigments, particularly Lithol Red. By 1963, the development of a continuous Tobias acid plant was under investigation at Bound Brook. The main emphasis was on changes in the first manufacturing step, the time-consuming sulfonation to Armstrong acid, and the time- and labor-consuming purification.

By changing the reaction conditions other products are favored. Thus Armstrong acid rearranges to 2-naphthol-6-sulfonic acid, known as Schaeffer's acid, which on further sulfonation affords 6,8- and 3,6-disulfonic acids, named G- and R-acid, respectively, because of the yellowish (gelb) and reddish colors of their azo dyes. The sulfonation mixture contains other sulfonic acids that are of no technical value and complicate the isolation of the main products. R-acid, as its salt (most sulfonic acids are isolated and used as alkali metal salts), was produced at Bound Brook in the 1960s at the rate of 500,000 lbs. per year. The process involved an 18-hour sulfonation of beta-naphthol with 98 percent sulfuric acid at 125°C to yield a mixture of R and other acids. The R-salt was obtained by selective precipitation, involving neutralization, slurrying, and three separate filtrations in filter presses. Recovery of R-salt was about 67 percent, giving an overall yield of 50 percent. Some 80 percent of the labor usage was in the recovery and purification steps.

When beta-naphthol is heated with aqueous ammonium sulfite or bisulfite in an autoclave it is converted to beta-naphthylamine by the Bucherer reaction. Beta-naphthylamine was one of the intermediates at one time purchased by Calco. It is highly carcinogenic and from the 1950s was no longer employed in dye manufacture.

The acid sulfate of alpha-naphthylamine (made by direct nitration of naphthylamine and subsequent reduction) undergoes rearrangement on heating to 1-naphthylamine-4-sulfonic acid, or naphthionic acid. It was, for example, coupled with diazonium salts of diamines of the benzidine series. The reverse

Bucherer reaction converts naphthionic acid into 1-naphthol-4-sulfonic acid, called Nevile–Winter acid.

Diazotization and coupling

The azo colorants are characterized by the presence of the atomic grouping made up of two nitrogen atoms, –N=N–, the azo group. The general method of preparation involves two steps, the first of which is diazotization of an aromatic or heteroaromatic (that is, an aromatic ring of carbon and other atoms) primary amine, one that contains the NH_2 atomic grouping. At Bound Brook, this took place in cypress wood or Haveg diazotization tubs. The second step is the coupling of the resulting diazonium salt with a coupling component in steel tubs. Typical coupling components include the naphthylamine and beta-naphthol derivatives, phenols, toluidines, and *N*-alkylated and *N*-arylated derivatives (such as *N,N*-diethylaniline). The coupling reaction of diazonium intermediates with hydroxyl-containing components is generally carried out in alkaline solution. Arylamines are coupled in weakly acidic solution. Low temperatures are employed, making necessary tremendous amounts of ice in industrial practice. Calco chemists developed a process that required less ice than formerly. At the end of the reaction, salt is added to precipitate the desired product. A wide range of structural variations is possible with azo dyes.

Monoazo dyes are obtained by a single diazotization and coupling sequence A>E, where A is the primary amine, and E is the coupling component. The arrow means “diazotized and coupled with.” Color in part depends on the length of the conjugated chain of alternating double and single bonds. With simple E components, greenish-yellows are obtained; with phenols and anilines, reddish-yellows; with naphthols, oranges; and with certain aminophenols, reds. The diazonium intermediate also contributes to the final color. Naphthylamines give deeper shades than anilines.

Disazo dyes contain two azo groups, and can be produced with more than one sequence of diazotization and coupling steps. For example, aromatic amines containing two amino groups, such as benzidine (D component) can be tetrazotized, that is, both amino groups are diazotized, and coupled with two dissimilar equivalents of coupling components E1<D>E2, making use of differing rates of coupling of the two diazonium salt groupings. These dyes, nowadays restricted to certain congeners of benzidine, afford deep shades as a result of extensive conjugation.

Anthraquinone Vat Dyes

When in 1906, American chemists gathered in New York to honor the jubilee of William Henry Perkin's mauve, there was no question that "the greatest triumphs of this branch of the industry are the artificial production of alizarin [1869] and indigo [1897]." However, there were many others, practically all of German origins: "Today [1906] about 2,000 individual dyestuffs are known, giving the whole range of the colours of the rainbow, and complying with every demand of taste, fashion, and stability. They surpass in beauty and brilliancy the colours supplied by nature, and, contrary to the impression prevailing among the public, the shades obtained with some of them are faster to the influence of time, light, and chemicals than the fastest which nature produces." No doubt the writer had in mind the then recently introduced cotton vat dyes based on anthraquinone, the intermediate from which alizarin was produced.

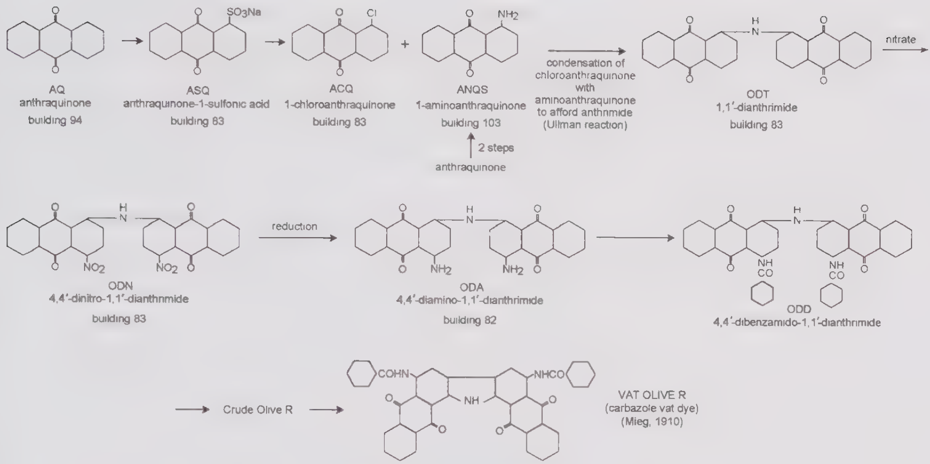
Vat dyes are important in the blue-green region. Their brightness, laundry-, and light-fastness render them ideal as colorants for curtains, shirtings, towels, and beachwear, and despite the multi-stage syntheses, which make them expensive, vat dyes were important throughout the half century, 1930–80, that they were made at Bound Brook.

The story of anthraquinone, or anthraquinonoid, vat dyes began in 1901, when René Bohn, head of the alizarin laboratory at BASF, applied the synthetic indigo reaction conditions to 2-aminoanthraquinone and discovered the blue colorant he named indanthrone, from *ind*igo and *anthr*aquin*one* (and later known as Indanthrene blue RS). Indanthrone consists of two anthraquinone units joined through a 1,4-diazine ring. In 1903, Roland H. Scholl worked on its structure and formation. Robert Emanuel Schmidt and other chemists at the Bayer company established the structure, and industrial research laboratories began to seek out other vat dye intermediates. In 1904, Bally, an assistant of Bohn, synthesized benzanthrone (BZN) from anthraquinone (AQ). Alkali fusion affords dibenzanthrone (DBZY), a blue dye called violanthrone in the trade.

Prior to 1914, Morton Sundour Fabrics of Carlisle, Scotland, was probably the largest user of the German-made vat dyes. Sir James Morton, the proprietor, later recalled that during German Army maneuvers in 1913, the capes and hats of the Emperor Kaiser Willem II, his sons and field marshals, all bore the "Sundour" brand. Morton's supply of vat dyes was critical to the success of his business, but dried up in August 1914, which left him and his dyers to sort out the riddle of their constitutions, starting with silver salt, anthraquinone-2-sulfonic acid. This, Morton said was "a word that was purest Hebrew to me at that time, but which for many days to come I had to assimilate with my morning coffee." The assimilation was successful, and in 1915 Morton's staff produced the first anthraquinone dyes in Britain. In 1919, Morton established Scottish Dyes, Ltd. The following year, Morton's chemists invented Caledon Jade Green, the 16,17-dimethoxy derivative of dibenzanthrone, that became the most widely produced vat dye in the world. Bound Brook was the leading, and last, producer in the United States.

The significance of 1-aminoanthraquinone (ANQS) to vat dye manufacture has been emphasized by Heinrich Zollinger: "Only 13 years ago [1974] Bien and Wunderlich stated that 80 to 90% of all industrially produced anthraquinone derivatives were based on anthraquinone sulfonic acids and among these 90% were derivatives of the 1-sulfonic acid. However, anthraquinone-1-sulfonic acid [ASQ] can only be obtained by mercury-(II)-ion catalyzed sulfonation [and] is the precursor of 1-aminoanthraquinone, the most important of all anthraquinone derivatives" (*Color Chemistry*, 159-60). Since the conversion of the sulfonic acid to the amino compound required arsenic, this, together with the use of mercury in the previous step, created environmental difficulties. By the 1970s, direct nitration of anthraquinone to 1-nitroanthraquinone (NAQ), with subsequent reduction to ANQS had been achieved, and was introduced at Bound Brook for use in the production of Vat Olive T and other vat colorants.

The vat dyes are of negligible solubility, and because of this have to be applied to cotton in the reduced, or leuco, form. This encour-



Vat Olive R (Bound Brook abbreviations)

aged the search for water-soluble vat dyes. In Germany, a process was developed for producing soluble vat dyes by reduction in pyridine containing sulfur trioxide and a metal. Once attached to cloth the reduced form was re-oxidized under acidic conditions to give the insoluble dye. Soluble vat dyes were extensively researched at Bound Brook from the late 1940s.

At first, vat dyes, as with the alizarin colorants, were produced from anthracene-derived anthraquinone. In the United States, an important development during World War I was the building up of anthraquinone derivatives through Freidel–Crafts acylation of benzene (and later of halogenated benzene and phenols) with naphthalene-derived phthalic anhydride, followed by cyclization of the resulting *ortho*-benzoylbenzoic acid (OBB), or its derivative. This not only provided routes to novel anthraquinones but removed the American dependence on imported anthracene and anthraquinone for vat dye manufacture. The Selden Company held the U.S. monopoly on the production of phthalic anhydride. In 1919, James Morton acquired rights from Selden to manufacture and sell naphthalene-derived phthalic anhydride in Britain. From around 1930, Bound Brook converted Selden's phthalic anhydride into anthraquinone derivatives.

At Bound Brook in the 1960s, Jade Green, Vat Grey 2G-2 and

Vat Olive Green accounted for more than half of the total vat dye production. The other thirty-two vat dyes included Vat Olive T, an anthrimide made by condensation of dibromo-, or dichloro-, benzanthrone with ANQS, Vat Brown R, and Vat Olive R, the latter two both made by similar condensations, followed by cyclization to afford carbazole rings.

Filtration and drying are important steps in the production of dyes. They require time and labor. Department G (vat dyes) at Bound Brook, for example, employed filter presses for separating suspended solids from liquids, generally in the form of a slurry. This was achieved by forcing the liquid through a suitable filter medium, which supported the solid, under applied pressure. For an acidic slurry, wooden plates and frames were used. The opening and closing of the press at each cycle caused considerable wear on the filter cloths. Due to deterioration, plates and frames were replaced frequently. There were around eighty filter presses, about half of them made of wood, and twenty-five of cast iron, in Department G. Generally, the vat dye press cake was washed with water, though in a number of cases nitrobenzene was used. After filtering, solids were dried in Calco hot air dryers.

Application of Dyes: Anchoring Dye on Fiber

Dyeing is normally readily accomplished in aqueous solution, often in the presence of a fixing agent, or mordant. This is ideal for cotton, silk, and wool, but not for certain synthetic fibers, such as nylon and polyester. The latter are plastic in nature, and require *disperse dyes*. Here the dyeing process involves heating the fiber in an aqueous dispersion of a water-insoluble dye. A solid solution is formed in the fiber. To penetrate synthetic fibers a small dye molecule is required, for which simple water-insoluble mono-azo dyes are ideal. Apart from yellow dyes (where phenolic components are common), these are usually based on *N*,*N*-dialkylated aniline coupling components that permit a wide range of shades to be obtained. They are complemented on nylon with *acid dyes*, which give more uneven coverage, but that have better fastness properties.

Polyester and cellulose triacetate ("acetate") fibers are much more hydrophobic than nylon and penetration of the fiber is difficult. Small molecular size is of even greater importance. In these cases *disperse dyes* alone are suitable. Atomic groupings that enable the dye to resist sublimation are incorporated. This is because dyed polyester fiber articles are often steam-pleated.

Anionic water-soluble mono and bisazo/disazo dyes made from sulfonated intermediates are used as *acid dyes* for wool and nylon. The sulfonic acid groups of these dyes form salts with the amino groups in the fibers. For wool, incorporation of a long alkyl chain gives increased fastness to washing. The cationic *basic dyes* are employed in the dyeing of polyacrylonitrile fiber, such as American Cyanamid's Creslan. They form a salt linkage with carboxylic and sulfonic acid groups incorporated in the fiber.

The very hydrophobic cellulosic fiber cotton does not contain basic or acidic groups. However, *direct dyes*, most of which belong to the azo class, including the bisazo benzidine derivatives, are directly adsorbed on to cotton. These dyes possess the property of cotton substantivity through hydrogen-bonding with the fiber, or with their own kind, accumulating within the fiber pores, thereby providing resistance to fading during washing and cleaning.

An alternative approach to the dyeing of cotton depends upon the formation of an insoluble dye on the fiber using *azoic dyes*. These colorants are prepared by condensation of an arylamine with beta-oxynaphthoic acid (BON), or 2-hydroxy-3-naphthoic acid. The arylamides, congeners of Naphthol AS (2-hydroxy-3-naphthanilide), show good cotton substantivity.

A far better method of dyeing cotton is by using *reactive dyes*, those that form chemical bonds with the fiber. They were introduced by ICI in England during 1956, soon after by other dye-makers, including CIBA and Hoechst, and later by American Cyanamid at Bound Brook.

Fastness

Successful dyes should resist the action of soap and light. Photochemical degradation of azo compounds involves scission of the azo linkage. Light fastness is enhanced by substituents that withdraw electrons from a conjugated system. This reduces the availability of electrons in azo-nitrogen atoms. The presence of bulky substituents *ortho* to the azo-linkage, inhibiting approach to the linkage, is also beneficial. A further means of protecting the azo-linkage against photodegradation is by the formation of stable complexes with a number of metals, in particular, chromium and cobalt. Chromium 1:2 and 1:1 complexes are important, and have good light-fastness. The incorporation of metals into dyes dates from the early 20th century. Metal-complex shades cover the whole spectrum, though they are generally duller than those of the unmetallized dyes. The dyed woolen cloth for suitings must be of a deep shade and fast, but not bright, and for this chromium and cobalt complexes of azo dyes are used. (C. V. Stead, "Colour Chemistry," in *Basic Organic Chemistry*, 323–31.)

Sources and further reading:

David Duff, "A Colourful Tale," *Chemistry in Britain* 37 (January 2001): 36–37.

Stanley D. Forrester, "A History of the Grangemouth Dyestuff Industry," *Chemistry in Britain* 21 (December 1985): 1086–88.

Morris R. Fox, *Dye-Makers of Great Britain, 1856–1976: A History of Chemists, Companies, Products and Changes* (Manchester: ICI, 1987), esp. 155–65.

J. Gunthard, "Recent Advances in the Field of Acid and Substantive Anthraquinone Dyestuffs," *American Dyestuff Reporter* 46, no. 1 (January 14, 1957): 9–21.

H. A. Lubs, ed., *The Chemistry of Synthetic Dyes and Pigments* (American Chemical Society Monograph Series) (New York: Reinhold, 1955).

James Morton, *History of the Development of Fast Dyeing and Dyes. A Lecture Delivered Before the Royal Society of Arts, 20th February 1929* (Carlisle: Morton Sundour, 1929).

Raphael Meldola, Arthur G. Green, and John Cannell Cain, eds., *Jubilee of the Discovery of Mauve and of the Foundation of the Coal-Tar Colour Industry by Sir W. H. Perkin, F.R.S., D.Sc., LL.D., Ph.D., Dr.Ing.* (London: Perkin Memorial Committee, 1906).

C. V. Stead, "Colour Chemistry," in *Basic Organic Chemistry* Part 5, *Industrial Products*, ed. J. M. Tedder, A. Nechvatal, and A. H. Jubb (London: Wiley, 1975), 315–50.

Heinrich Zollinger, *Color Chemistry: Syntheses, Properties and Applications of Organic Dyes and Pigments* (Weinheim: VCH, 1987).

CHAPTER NOTES

The Papers of Victor L. King held at Dartmouth College Library, Hanover, New Hampshire, are identified as King Papers, MS 429, Dartmouth College Library.

Documents in the file of Dr. Neil M. Mackenzie and other relevant material held at Bound Brook Memorial Library, New Jersey, are identified as Bound Brook Memorial Library.

Items held at the Sidney M. Edelstein Library for the History and Philosophy of Science, Technology and Medicine are identified as Edelstein Library.

Items held at the Sidney M. Edelstein Center for the History and Philosophy of Science, Technology and Medicine are identified by a reference "SME," followed, where relevant, by an abbreviation that indicates the folder or collection. The latter are:

AmCy: American Cyanamid.

EK: Erwin Klingsberg.

RS: Regina Schoental Archive (Toxicology).

Transcripts of New Jersey Department of Environmental Protection (and its predecessors) and Environmental Protection Agency, Region 2, documents held at the Sidney M. Edelstein Center are designated TSME.

INTRODUCTION

1. For the important photograph collection of Nathan Gallup Williams Haynes (1886–1970), now at Chemical Heritage Foundation, Philadelphia, see Kristin Clark, "The Williams Haynes Portrait Collection," *Chemical Heritage* 19, no. 2 (Summer 2001): 16–17.
2. Krishnasamy Venkataraman, *The Chemistry of Synthetic Dyes*, 2 vols. (New York: Academic Press, 1952), vol. 1, 13.
3. See, in particular, Peter J. T. Morris "Vom Buna zum Hi-Fax: Technologietransfer von Deutschland in die Vereinigten Staaten auf dem Gebiet der Polymere (1925–1960)," and Raymond G. Stokes, "Flexible Reaktion: Die Bedeutung des Technologietransfers für die deutsche Chemieindustrie (1925–1961)," in *Technologietransfer aus der deutschen Chemieindustrie (1925–1960)*, ed. Rolf Petri (Berlin: Duncker & Humblot, 2004).

4. See for example Neil Gussman, "Innovation and Chemical Creativity in Chemical R&D," *Chemical Heritage* 21, no. 3 (Fall 2003): 36.
5. R. G. Krupp, "Research Report Symbol Designations Explained: Review of Current Practices for Designating Research Division Reports at Bound Brook, Pearl River, and Stamford," *Research Division News*, March 1958, 7–11, on 11.

CHAPTER ONE

1. *What We Do at Calco: A Series of Ten Articles Reprinted from the Plainfield* Courier-News *April 1941* (Bound Brook: Calco Chemical Division, American Cyanamid Company, 1941), third article.
2. Rev. Titus E. Davis, *The Battle of Bound Brook* (Chronicle Steam Printery, 1895). The Battle of Bound Brook, April 12, 1777, is well described in the translation of the diary of a Hessian soldier who fought with the British, Johann von Ewald, *Diary of the American War: A Hessian Journal* (New Haven, Conn.: 1979).
3. This description of the site is based on information supplied by Isaiah Von, and the unpublished typescript reminiscences of C(ornelius) Marsden Vanderwaart, 35.
4. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50, 1915–1965* (Bound Brook: American Cyanamid Company, 1965), 23–4.
5. Accounts of the 19th-century synthetic dye industry include: Anthony S. Travis, *The Rainbow Makers: The Origins of the Synthetic Dyestuffs Industry in Western Europe* (Bethlehem, Pa.: Lehigh University Press, 1993); Carsten Reinhardt and Anthony S. Travis, *Heinrich Caro and the Creation of Modern Chemical Industry* (Dordrecht: Kluwer, 2000); and Johann Peter Murmann, *Knowledge and Competitive Advantage: The Coevolution of Firms, Technology, and National Institutions* (Cambridge: Cambridge University Press, 2003). A useful summmary of the technical and historical background to cyananide production is M. L. Kastens and W. G. McBurney, "Calcium Cyanamide," in *Modern Chemical Processes: A Series of Articles Describing Chemical Manufacturing Plants* (New York: Reinhold Publishing Corporation, 1952), vol. 2, 97–110. For the impact of the Haber–Bosch process see Anthony S. Travis, "High Pressure Industrial Chemistry: The First Steps, 1909–1913, and the Impact," in *Determinants in the Evolution of the European Chemical Industry, 1900–1939: New Technologies, Political Frameworks, Markets and Companies*, ed. Anthony S. Travis, Harm G. Schröter, Ernst Homburg, and Peter J. T. Morris (Dordrecht: Kluwer, 1998), 3–21; and Vaclav Smil, *Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production* (Cambridge, Mass.: MIT Press, 2001).
6. Sources for historical background include: [Williams Haynes] *Dyes Made in America, 1915–1940* (Bound Brook: Calco Chemical Division, American Cyanamid Company, 1940); *What We Do at Calco*; *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*; and Williams Haynes, *American Chemical Industry*, 6 vols. (New York: D. Van Nostrand, 1945–54).
7. Williams Haynes, "On the Chemical Frontier: The Cyanamid Story," typescript,

1957 (title page marked "Doubleday & Company, Garden City, N.Y."), 123, Edelstein Library (hereafter Haynes).

8. Kathryn Steen, "Wartime Catalyst and Postwar Reaction: The Making of the United States Synthetic Organic Chemicals Industry, 1910–1930" (Ph.D. diss., University of Delaware, 1995), 96 (UMI microform 9610494, 1996) (hereafter Steen).
9. *Dyes Made in America*, 4.
10. According to Haynes, "they knew nothing about making coal-tar intermediates, but they did know a great deal about coal-tar dyes and their application. They had a laboratory and a chemist and they brought in two men who knew how a chemical plant worked. For good measure they engaged Treat B. Johnson ... as consultant," Haynes, 124. Treat Baldwin Johnson received his Ph.B. from Sheffield Scientific School, Yale, in 1898. He was appointed assistant professor in 1908, and full professor in 1917, and during 1926–27 was president of the American Institute of Chemists.
11. *Dyes Made in America*, 10.
12. Haynes, 129.
13. Ibid., 127.
14. Robert C. Jeffcott, vice president and manager, Cott-A-Lap Company, report to stockholders, June 30, 1915. Quoted in "Our Golden Anniversary, 1957," *Bound Brook Diamond* 22, no. 23 (June 13, 1957).
15. Haynes, *American Chemical Industry*, vol. 3, *The World War I Period: 1912–1922*, 215–17.
16. J. H. McMurray and F. H. Chamberlain, "Early History of Calco," published in 10 installments (one by F. H. Chamberlain), *Calco Diamond*, April 1935–January 1936.
17. Haynes, 127-8.
18. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 7.
19. Ibid., 6.
20. Ibid., 7.
21. J. H. McMurray, "Early History of Calco," *Calco Diamond* 1 (May 1935): 1.
22. F. H. Chamberlain, "Early History of Calco," *Calco Diamond* 1 (September 1935): 1.
23. Steen, 182–3. See also John Shorter, "Bernhard Jacques Flürscheim (1874–1955): Organic and Theoretical Chemist," *Ambix* 50 (2003): 274–301.
24. Haynes, 131. The power station of the West Works "contained two 300 KW turbines, two ... air compressors, four 325 HP B&W [Babcock & Wilcox] boilers with the necessary pumps, fans, switchboards, etc., and a pumping station situated on the Raritan River with a pipeline to the plant–a distance of approximately 1,400 ft." Chamberlain, "Early History of Calco," 1.
25. McMurray, "Early History of Calco" (October 1935), 1.
26. Ibid., 1–2.
27. Chamberlain, "Early History of Calco," 1–2. Chamberlain noted that among the staff "who did heroic work during this period was the late Mr. Harry Berry, who was not only deeply respected by all who came in contact with him but loved by all of us." Colonel Weeks, born in Lyons, New York, held B.S. (1910) and LL.B. (1912)

degrees from the University of West Virginia. He was a West Point graduate, and served in the army during 1905–20.

28. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 9. See also Bernhard J. Flürscheim, "Some Properties of Tetranitraniline (TNA)," *Journal of the Society of Chemical Industry* 40 (1921): 97T–107T, which includes Beardsley's observations on the density and appearance of the crystalline product (97T).
29. David H. Wilcox Jr., "The American Chemical Society Prize Essay Contests, 1923–31," *Journal of Chemical Education* 39 (1962): 77–82, on 77.
30. U.S. Tariff Commission, 1919. See Steen, 235. CIBA, Geigy and Sandoz jointly purchased the Ault & Wiborg organic colorants facility in 1920.
31. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 10. King described how the process was scaled up. "The Cinchophen was manufactured ... in a plant in Newark and when the doctor in charge of this operation took me out to explain it, I found a building with a long table against the wall and on this table there was mounted glass laboratory equipment consisting of Erlenmeyer flasks with glass condensers and receivers. I watched the operator make up the Cinchophen ... There were over a hundred of these flasks. He then connected all the glass work up and cooked it. At the end of the cooking, he went along dumping all the flasks into a big pot for refining and working up. I asked the doctor why this was done in so many small units; he assured me that there were volumes of research reports in Bound Brook that had proven that it was impossible to make this Cinchophen in larger batches, otherwise the yield would decline with great rapidity. Naturally, I didn't believe that and took steps to get as big an enamel kettle as I could buy to make this product in a manufacturing way. The doctor felt very strongly on this subject and without my knowing it, took this occasion to call on the president of the company one evening and told Mr. Jeffcott to fire this guy King in a hurry as he was going to wreck the place. I suppose he explained I was going to make it in large batches. Mr. Jeffcott, who was not a chemist, nevertheless saw the fallacy in this making and asked the doctor–well, if it is true that you must make it in small batches and bigger batches will ruin the yield, then why do you work in Erlenmeyer flasks on a large scale–why don't you employ thimbles? Apparently, this broke up the meeting and nothing was done; at least I didn't get fired but the doctor, who was a good sport, later told me this story by himself." (The "doctor" was perhaps Fine.) Victor L. King, "The Technical Department," paper to Calco student trainees, April 27, 1946, 6. King Papers, MS 429, Dartmouth College Library. Abbott Laboratories also produced Cinchophen during World War I.
32. McMurray, "Early History of Calco" (November 1935), 1–2.
33. Haynes, 130.
34. Russell McCarty to Neil M. Mackenzie, undated note, Bound Brook Memorial Library. McCarty attended the American Locomotive Technical School, joined Calco in 1917, and retired in 1958. He died in 1994, at age 101
35. Haynes, 135.
36. M. L. Crossley and P. V. Resenvelt, "Color and Constitution. I. Preliminary Paper. Effect of Isomerism on the Color of Certain Azo Dyes," *Industrial and Engineering Chemistry* 16 (1924): 271–73. This was from a paper presented to the

American Chemical Society's Division of Dye Chemistry at the September 1922 Pittsburgh meeting.

37. Crossley received honorary D.Sc. degrees from Brown and Wesleyan universities. For biographical details see "A.C.S. Candidates for 1940," *Industrial and Engineering Chemistry* 31 (1939), *News Edition* 17, no. 20 (October 20, 1939): 653; A. D. McFadyen, "Moses Leverock Crossley," *Chemical Industries* 51 (1942): 510–11, 557, 621; and David H. Wilcox Jr., "Moses Leverock Crossley," in *American Chemists and Chemical Engineers*, ed. Wyndham D. Miles (Washington, D.C.: American Chemical Society, 1976), 102–3.
38. Victor L. King, career profile, December 1, 1926, 2. King Papers, MS 429, Dartmouth College Library (hereafter King, career profile). See also obituary in *New York Times*, October 13, 1958, and *American Men of Science*, 9th ed., P., s.v. "King, Victor Louis."
39. Victor L. King, "A Rough but Brilliant Diamond," *Journal of Chemical Education* 19 (1942): 345. See also Peter J. Ramberg, "Paper Tools and Fictional Worlds: Prediction, Synthesis and Auxiliary Hypothesis in Chemistry," in *Tools and Modes of Representation in the Laboratory Sciences*, ed. Ursula Klein (Dordrecht: Kluwer, 2001), 61–78, on 68, 70.
40. David H. Wilcox Jr., "Werner and Dyes," in *Werner Centennial: A Symposium Co-sponsored by the Division of Inorganic Chemistry and the Division of the History of Chemistry at the 152nd Meeting of the American Chemical Society, New York, N.Y., Sept 12–16, 1966*, symposium chairman George B. Kauffman (Washington, D.C.: American Chemical Society, 1967), 86–102, on 91–2.
41. King, career profile, 4–5. Acetanilide was used as an accelerator for vulcanizing rubber and as an antiseptic. Paranitr[o]aniline was a dye intermediate. For Edison's involvement with the manufacture of aromatic chemicals see Byron M. Vanderbilt, *Thomas Edison, Chemist* (Washington, D.C.: American Chemical Society, 1971), 234–58, esp. 255. Thomas A. Edison, Inc., was merged with the McGraw Electric Company in 1957, to form the McGraw-Edison Company.
42. King, career profile, 5.
43. The Edison phenol facilities were shut down in 1917, from which time King's services were no longer required. The manufacture of phenol after the mid-1920s was generally based on hydrolysis of chlorobenzene, a process first developed commercially by Dow Chemical Company. Don Whitehead, *The Dow Story. The History of the Dow Chemical Company* (New York: McGraw-Hill, 1968), 97–8.
44. King, career profile, 8. During 1917–18, King undertook consultancy work for several chemical manufacturers, including Charles Pfizer & Co. in Brooklyn.
45. Ibid., 7–8.
46. Ibid., 9. Mr. Berry was probably George A. Berry, rather than Harry Berry who was also involved in early work at Calco.
47. Ibid., 10. Haynes, chapter 1, note 3: "Capitalization of the new independent Calco Chemical Co. was $2,000,000 1st. pfd., 7%; $1,000,000 2nd. pfd., 6%; $2,000,000 common, $100 par; financed by Bonbright & Co. which sold 20,000 shares of common at par. During the 1920s additional financing was accomplished and a non-voting Class B common added."

48. Shreve, a founding member of the American Association of Textile Chemists and Colorists in 1921, was author of *Dyes Classified by Intermediates* (New York: Reinhold, 1922), and served on the editorial committee responsible for the first edition of the *Colour Index*, published by the British Society of Dyers and Colourists in 1924.
49. R. Norris Shreve, "Alkylation," *Industrial and Engineering Chemistry* 44 (1952): 1972–79. See also Nikolaos A. Peppas and Ronald S. Harland, "Unit Processes Against Unit Operations: The Educational Fights of the Thirties," and "Chemical Engineering at Purdue University," in *One Hundred Years of Chemical Engineering*, ed. Nikolaos A. Peppas (Dordrecht: Kluwer, 1989), 125–42, and 263–99, on 293. Shreve's *The Chemical Process Industries* (Chemical Engineering Series) (New York: McGraw-Hill, 1945) includes illustrations of Bound Brook and other American Cyanamid manufacturing facilities. Chapter 38, "Intermediates, Dyes, and their Application," contains flow diagrams for several important processes used in the manufacture of intermediates and dyes, as well as economic information (836–902). The various editions of this book eventually sold 180,000 copies. In the 1950s, Shreve became involved in the development of Cheng Kung University, Taiwan. His collection of Chinese jade and other Asian works of art are displayed at the Indianapolis Museum of Art. It was at MIT in the 1920s that chemical engineering became a theoretical discipline based on unit operations, such as transport of materials, heat transfer, and separation, as originally proposed by the consultant Arthur D. Little. Shreve's contribution was the addition of unit processes, such as those employed in the manufacture of synthetic organic chemicals, including nitration, reduction, and oxidation. In *The Chemical Process Industries* he listed twenty-five important unit processes and eighteen unit operations (20).
50. Robert Wizinger, "Second-order Absorption Colours," *Palette*, no. 24, 1966, 24–29. *Palette* was published by Sandoz.
51. The Piccard family papers, which include a number of Jean Felix Piccard's documents relating to aromatic intermediates and colorants, are in the Manuscript Division, Library of Congress, Washington, D.C. See also, Marlene Bradford and Anthony N. Stranges, "Auguste and Jean-Felix Piccard," in *Dictionary of World Biography, 20th Century* (Pasadena: Salem Press and Fitzroy Dearborn, 1999), vol. 9, 3002–5.

CHAPTER TWO

1. Kathryn Steen, "Wartime Catalyst and Postwar Reaction: The Making of the United States Synthetic Organic Chemicals Industry, 1910–1930" (Ph.D. diss., University of Delaware, 1995), 240–44 (UMI microform 9610494, 1996) (hereafter Steen).
2. Steen, 254–58, 287–97. Jeffcott was president of the American Dyes Institute during 1920–22.
3. Edwin E. Slosson, "The Influence of Coal-Tar on Civilization," in *Science:*

Remaking the World, ed. Otis W. Caldwell and Edwin E. Slosson (New York: Garden City Publishing, 1923), 48–77, on 52–54.

4. Ibid., 53. See also Haynes, *American Chemical Industry*, 6 vols. (New York: D. Van Nostrand, 1945–54), vol. 4, *The Merger Era* (1948), 238. R. Norris Shreve was a member of a special committee appointed to ensure that the work of the Color Laboratory satisfied the needs of dye users.
5. Slosson, "The Influence of Coal-Tar on Civilization," 71.
6. Ibid, 70–1.
7. Ibid, 71
8. Ivan Gubelmann, "Relation of the Dyestuff Industry to Other Industries," *Industrial and Engineering Chemistry* 27 (May 1935): 618–26, on 619. For the history of dye making at DuPont during 1917–1980, see P. J. Wingate, *The Colorful Du Pont Company* (Wilmington, Delaware: Serendipity Press, 1982).
9. A. H. Pierce to Williams Haynes, July 30, 1946. Quoted in Williams Haynes, *American Chemical Industry*, vol. 4, *The Merger Era*, 230n.
10. Williams Haynes, "On the Chemical Frontier: The Cyanamid Story," typescript, 1957 (Title page marked "Doubleday & Company, Garden City, N.Y."), 132–3, Edelstein Library (hereafter Haynes).
11. David A. Hounshell and John Kenly Smith Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980* (Cambridge: Cambridge University Press, 1988), 95–97 (hereafter Hounshell and Smith).
12. Haynes, 131.
13. "Production and Sales of Dyes Decline," *Industrial and Engineering Chemistry* 17 (1925): 543.
14. Steen, 338–46.
15. Kathryn Steen, "German Chemicals and American Politics, 1919–1922," in *The German Chemical Industry in the Twentieth Century*, ed. John H. Lesch (Dordrecht: Kluwer, 2000), 323–46. The United States was officially at war with Germany until the summer of 1921.
16. Kathryn Steen, "Dyes in the Treaty of Versailles," *Chemical Heritage* 19, no. 4 (Winter 2001/2): 22–3.
17. Kathryn Steen, "Patents, Patriotism, and 'Skilled in the Art': *USA v. The Chemical Foundation, Inc.*, 1923–1926," *Isis* 92 (2001): 91–122. See also Haynes, *American Chemical Industry*, vol. 4, *The Merger Era*, 240–1. At the time of the case, Freedman was working with H. A. Metz. In 1923, Calco's assets were valued at around $7 million, comparable to Dow Chemical, though considerably less than DuPont, at $280 million, and Allied Chemical & Dye, at $294 million.
18. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50, 1915–1965* (Bound Brook: American Cyanamid Company, 1965), 10. For Kerin Manufacturing Co., see Haynes, *American Chemical Industry*, vol. 4, *The Merger Era*, 538–9.
19. "Dye Census for 1924 Shows a 27% Decline in Production from 1923 Total of 93,667,52 Pounds; Intermediates Largely Imported from Germany; We Now Make 93% of Our Dyestuff Consumption," *Chemicals (A Consolidation of Chemical, Color & Oil Record; Chemical Age and The Chemical Engineer; Color Trade Journal and Textile Chemist)* (Dyestuffs Number) 23 (September 14, 1925): 5.

20. Calco Chemical Company advertisements, *Chemicals* (Dyestuffs Edition) 24 (May 25, 1925): 16 and 72.
21. John H. McMurray, "Early History of Calco," *Calco Diamond* 1 (June 1935): 1.
22. Gubelmann, "Relation of the Dyestuff Industry to Other Industries," 619.
23. "Spring Color Card, 1927," *Chemicals* (Technical Number) 26 (November 22, 1926): 39.
24. Arnold Thackray, Jeffrey L. Sturchio, P. Thomas Carroll, and Robert Bud, *Chemistry in America 1876–1976. Historical Indicators* (Dordrecht: D. Reidel, 1984), 123, n.12.
25. Hounshell and Smith.
26. Ibid., 297–300.
27. Clarence J. West and Ervye L. Risher, *Industrial Research Laboratories of the United States Including Consulting Research Laboratories* (Washington, D.C.: National Research Council, 1927), 3rd ed., revised and enlarged.
28. "Reports written by Research personnel were designated as I.R. (Investigation Reports), which had the same number as the originating I.O. (Investigation Order). This type of codification ... consisted of a project or perpetual order number." R. G. Krupp. "Research Report Symbol Designations Explained," *Research Division News*, March 1958, 7–11, on 7. This article reviewed "current practices for designating ... Research Division reports at Bound Brook, Pearl River, and Stamford."
29. Hounshell and Smith, 300–2, 369–71.
30. "Record Production of Dyes in 1928," *Industrial and Engineering Chemistry* 21 (1929): 404. Among the new entrants to vat dyes was National Aniline, which commenced their manufacture in 1927.
31. For Bell, see Kenneth C. Towe, *William Brown Bell, 1879–1950. Quaker, Lawyer, Business Leader. Molding the Future through Chemistry* (New York: Newcomen Society in North America, 1953), and Stephen H. Cutcliffe, "Bell, William Brown," in *American National Biography*, ed. John A. Garraty and Mark C. Carnas (New York: Oxford University Press, 1999), 518–20. Bell, who received his law degree from Columbia in 1913, became involved with chemical manufacture in 1917 when, representing Duke interests, he participated in the no. 2 Muscle Shoals hydroelectric nitrate plant.
32. Haynes, 61. Chapter 1, note 6: "The financial base of this campaign had been carefully laid. In February 1926, one American Cyanamid share of Class A Common and four shares of Class B Common, each of $20 par value, were issued in exchange for each share of $100 par Common outstanding. The A and B stock had the same rights, except that Class B was non-voting. In 1929 both A and B stocks were changed from $20 par to no-par value and the B shares increased from 400,000 to 1,600,000; of these latter 96,930 shares were exchanged 2-for-1 for the 6% preferred outstanding."
33. Authorized class "B" common shares were increased from 500,000 shares to 700,000 in January 1929.
34. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 11. Beaver "became known as the Damascus (Va.) Plant and was to become, down to the present day, the

oldest continuously operated acquisition of the Bound Brook Plant." See also Haynes, *American Chemical Industry*, vol. 4, *The Merger Era*, 44–5, and 231.

35. Harry D. Gibbs and Courtney Conover discovered the process when working at the Color Laboratory, Bureau of Chemistry, Department of Agriculture. A similar process was invented in Germany by Alfred Wohl. Following patent litigation, Wohl's process, that employed mercury vapor, was given priority, and the basic patent was assigned to I.G. Farben in 1934. American Cyanamid then developed a modified, patent-free process. In Europe, anthraquinone was generally made by direct oxidation of anthracene. See also Haynes, *American Chemical Industry*, vol. 4, *The Merger Era*, 44, 89, and, for intermediates and the early postwar period in general, 207–42.
36. "Calco Chemical Co. Aids Its Employees. Group Insurance Plan is Adopted by Management," *Bound Brook Chronicle*, November 22, 1929.
37. L. F. Haber, *The Chemical Industry, 1900–1930: International Growth and Technological Change* (Oxford: Clarendon Press, 1971), 315.
38. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 12.
39. *Lederle: A Division of American Cyanamid Company* (New York: American Cyanamid, 1950).
40. Chemical Construction Corporation was incorporated on February 6, 1930, in Delaware.
41. Haynes, *American Chemical Industry*, vol. 4, *The Merger Era*, 46. For the international implications see: Arjan van Rooij and Ernst Homburg, *Building the Plant: A History of Engineering Contracting in the Netherlands* (Zutphen: Walberg Pers/Eindhoven: Foundation for the History of Technology, 2002); and Ashish Arora and Nathan Rosenberg, "Chemicals: A U.S. Success Story," in *Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry*, ed. Ashish Arora, Ralph Landau, and Nathan Rosenberg (New York: Wiley and Chemical Heritage Foundation, 1998), 71–102, on 96–7.
42. R. Jeffcott to "Mac," June 5, 1933, Bound Brook Memorial Library. The value of American Cyanamid common stock had fallen over 70 percent since 1929.
43. *Calco Diamond* 1 (September 1935): 3.
44. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 11.
45. "Bakelite Corporation to Locate Its Factory Here," *Bound Brook Chronicle*, August 16, 1929. The article listed the following local chemical manufacturers, in addition to Calco: Hemingway & Co., formerly Somerset Chemical Co.; Acetylene Railroad Light and Signal Co.; King Chemical Co. (from which Calco purchased its sulfur dioxide department); and Peerless Color Co. In addition, Ruberoid was based in South Bound Brook, while Johns-Manville (Manville Corporation) was to the west of Calco. Hemingway & Co. was the Sherwin-Williams insecticide facility, located next to Calco.
46. Haynes, 117. The United States retained the gold standard until 1933. In the following year, President Roosevelt fixed the official price at which the Federal Reserve purchased and sold the metal to $35 an ounce.
47. Many of these firms and production units had been acquired by 1930, and their relationships with the parent American Cyanamid Company is best understood

through the Cyanamid "tree" in *Industrial and Engineering Chemistry, News Edition* 9, no. 10 (May 20, 1931): 157. *Calco Diamond* 2 (January 1936) provides supplementary information on acquisitions: December 1932, Noil Chemical & Color Works, Inc., New York, manufacturer of azo dyes; February 1933, Kent Color Corporation, Brooklyn, New York, alkylated aniline, methyl violet, and methyl violet ink; and, in 1935, Pfister Chemical Company, Ridgefield, New Jersey, vat and fast colors, and U.S. Tar Products, Matawan, New Jersey, naphthalene products.

48. Kenneth H. Klipstein obtained a bachelor's degree, majoring in economics, and master's in chemistry from Princeton. He was, successively, general manager of research, executive vice president, and American Cyanamid president (1961–65). He was founding chairman of the Chemistry Industry Council of New Jersey. In 1954, in honor of his father, he founded the Ernest Christian Klipstein Foundation of New Vernon, New Jersey.
49. Phenol was still made on a large scale by the Dow and sulfonation processes. In 1939–40 the process of Chemische Fabrik Dr. F. Raschig GmbH, of Ludwigshafen, Germany, was introduced into the United States by Durez Plastics and Chemicals Inc., of North Carolina. See Walter H. Prahl (Durez Plastics Division, Hooker Chemical Corporation), "The Hooker Phenol Process," *Chemical Engineer*, September 1964, no. 181, CE199–CE202, CE220.
50. According to Jay Leavitt, Sydite, a rubber processing chemical, was made in building 30 in a simple wooden tub. "I seem to recollect that it was named for Syd Moody, one of the Calco General Managers, but that may be apocryphal and/or incorrect." The process employed sodium sulfhydrate.
51. *Calco Diamond* 1 (September 1935): 3.
52. M. E. Fitzgerald, "Benz[anthrone], Dibenz[anthrone] & Iso[dibenzanthrone]. Calco Chem. Co. Inv[estigation] Report No. 7, 1938." Copies were distributed to R. A. Norton, G. M. Smith, H. Z. Lecher, the Research File, with two copies to the Technical File.
53. Fred Hoffman Rhodes, *Technical Report Writing* (Chemical Engineering Series) (New York: McGraw-Hill, 1941), quoting King, 2. See also "Why Chemists Get Fired," *Chemical Industries* 41 (1937): 41.
54. Peter H. Spitz, *Petrochemicals: The Rise of an Industry* (New York: Wiley, 1988), 222.
55. Until World War I, Carl Harwood Hazard was a sales manager at American Synthetic Color Co. In 1918, after serving as a lieutenant in the Chemical Warfare Service, he joined H. A. Metz as advertising manager. He set up the Hazard Advertising Company in New York during 1920, and remained president until his death in 1943. Though he represented a number of chemical firms, American Cyanamid and Wishnick-Tumpeer were his main clients. See *Chemical Industries* 53 (1943): 397.
56. Haynes, *American Chemical Industry*, vol. 4, *The Merger Era*, 46.
57. Harm G. Schröter, "Cartels as a Form of Concentration in Industry: The Example of the International Dyestuffs Cartel from 1927 to 1939," in *German Yearbook on Business History 1988* (Berlin: Springer-Verlag, 1990), 113–44, on 118.

58. Arora and Rosenberg, "Chemicals: A U.S. Success Story," in *Chemicals and Long-Term Economic Growth*, 71–102, on 84–86. Idem, Marco Da Rin, "Finance and the Chemical Industry," 307–39 and Haynes, *American Chemical Industry*, vol. 4, *The Merger Era*, 45–6.
59. Bell was president of the Chemical Alliance at a time when it worked with the National Recovery Administration. He chaired the national committee for modification of the industrial section in connection with the Securities Exchange Act of 1934, and was chairman of the Republican National Finance Committee in 1936.
60. "William B. Bell, "Recovery–by Alchemy or Chemistry," *Industrial and Engineering Chemistry* 27 (1935), *News Edition* 13, no. 9 (May 10, 1935): 188–90. A paper originally read before the 89th general meeting of the American Chemical Society, New York, April 22–26, 1935.
61. *Calco Diamond* 1 (October 1935): 2.
62. The sodium cyanide (Cyannatrium) convention was based on an informal agreement. I.G. Farben became a member following meetings held in January 1927 between the European members, with Degussa acting as representative of the other members of the German convention. The inclusion of I.G. Farben was confirmed by Degussa on January 10, 1927, the date of incorporation of the convention/agreement (although no formal contract was then drawn up). American Cyanamid did not appear in the contract of February 28, 1934. Instead, its British subsidiary, Cyanamid Products, and ICI were named as parties to the agreement, on the one side, with Degussa and the so-called Continental group on the other side. BASF Unternehmensarchiv, Vertragskartei Ludwigshafen, No. 384. The international cartel agreement was renewed several times, for the last time on January 19, 1937, for a period of four years. In 1944, the German group of the convention was forcibly united with other cartels (Rhodansalz-Convention, Deutsche Ferrocyan-Convention) by order of the Reich Ministry of Economics. BASF Unternehmensarchiv, Vertragskartei Frankfurt I, No. 938.

    In the 1930s, after the price of gold was increased, sale of cyanide was, as Haynes records, the main contributor to the profits of American Cyanamid. The involvement of Cyanamid Products instead of American Cyanamid is an example of how American companies participated in international cartels, despite the American anti-trust legislation.

    From 1930, there was a loose commitment (Interessenvertretung) on the part of Bell to initiate joint American Cyanamid–I.G. Farben chlorate production in the United States. American Cyanamid, according to Bell, would not engage in negotiations regarding production of chlorate with any company apart from I.G. Farben, which in turn agreed to abstain from making arrangements with other American companies. I.G. Farben wrote to Bell on August 28, 1930, and Bell returned the letter with the handwritten remark "Accepted on above conditions–American Cyanamid Company–By W. B. Bell, President." BASF Unternehmensarchiv, Vertragskartei Frankfurt I, No. 1039.

    There were also licensing arrangements concerning American Cyanamid's flotation agent Phosphokresol, with the first agreement, between American Cyanamid, I.G.

Farben, and Ellis Flotation Co., dated January 1, 1931, expiring on June 30, 1933. It was stipulated that American Cyanamid, as licensee of a patent of Ellis Flotation Co. for manufacture of the agent by reacting cresylic acid [cresol] with phosphorus pentasulfide, would grant a sub-license to I.G. Farben. Moreover, the parties to the contract agreed that I.G. Farben would manufacture and sell the product only in what was known as A Territory (Europe, Africa, excluding the Union of South Africa and Rhodesia, and Asia, excluding Japan and Korea). The B Territory (North and South America, Union of South Africa, Northern and Southern Rhodesia, and Japan, but excluding Korea and Australia) would be closed to I.G. Farben and would be the province of American Cyanamid. BASF Unternehmensarchiv, Vertragskartei Frankfurt I, No. 1135. On January 1, 1939, American Cyanamid and I.G. Farben entered into a similar agreement after the earlier arrangement had been amended several times (on November 8, 1930, January 22, 23, and 26, 1931, and March 19, 1931, and probably on other dates). The 1939 agreement applied to addition of another product of the same type, namely Aerofloat 31, which achieved better results with certain ores. Termination of the agreement was conditional to either party giving prior notice of not less than six months. BASF Unternehmensarchiv, Vertragskartei Frankfurt I, No. 2670; and BASF Unternehmensarchiv, Vertragskartei Ludwigshafen, No. 965. I thank Susan Becker of BASF Archives for provision of this archival information.

63. "Chemical Industry, I," *Fortune*, December 1937, 157–62.
64. Schröter, "Cartels as a Form of Concentration in Industry," 140. From 1939, Verein für Chemische und Metallurgische Produktion in Aussig was known as Verein für Chemische und Metallurgische Produktion in Prague.
65. For Lecher, see *American Men of Science*, 9th ed., P., s.v. "Lecher, Hans Zacharias."
66. During 1929–31, Eberhart (A.B., Ohio State, 1929) was a research chemist at DuPont, before joining Ohio State as a member of the junior staff. He received his master's from Ohio State in 1933. Other Calco research chemists included L. M. Shafer, in the azo plant during 1936, and A. W. Joyce, who joined the facility in 1936.
67. H. Z. Lecher to Neil M. Mackenzie, June 3, 1937. Bound Brook Memorial Library.
68. While many of those joining Bound Brook would embark on long careers with American Cyanamid, others would stay just one or two years before continuing studies or joining other chemical firms. They included Robert Roy White, who served as junior chemical engineer during 1936–37 before joining Dow, then Standard Oil (California), and eventually becoming professor of chemical engineering at the University of Michigan.
69. Kienle received his B.S. from Worcester Polytechnic in 1916, and M.S. from Union College, New York, in 1927.
70. Edwin I. Stearns, "Dyeing for a Living," *Dye-Chemlines* 13, no. 4 (August 1968): 1–2, on 2. Part 3 of a four-part excerpt from Stearns's address on the occasion of his acceptance of the Olney Medal in 1968.
71. For consensus in colorimetry see Sean F. Johnston, "The Construction of Colorimetry by Committee," *Science in Context* 9, no. 4 (1996): 387-420.

72. R. Robert Brattain, "Spectroscopy in World War II," *Spectrum* 26, no. 2 (October 1999), 1–7. Supplement to *Applied Spectroscopy* 53, no. 10 (1999).
73. "The Evolution of Woodstains" originally appeared in *Oil, Paint and Drug Reporter*, July 12, 1937. Peacock published a series of articles on "The Practical Art of Color Matching" in *Rayon Textile Monthly* during 1940–41. In October 1936, with Kienle, he published "The Coloring of Plastics" in *Modern Plastics.*
74. See, for example, Henry E. Millson, *The Phenomenon of Fluorescence* (Technical Bulletin 571, Calco Technical Division) (Bound Brook: American Cyanamid Co., 1941).
75. *Abstracts of Papers. 93rd Meeting, American Chemical Society, Chapel Hill, N.C., April 12 to 15, 1937* (Boston: Printed by Spaulding-Moss Co. [American Chemical Society], 1937).
76. John E. Lesch, "Chemistry and Biomedicine in an Industrial Setting: The Invention of the Sulfa Drugs," in *Chemical Sciences in the Modern World*, ed. Seymour H. Mauskopf (Philadelphia: University of Pennsylvania Press, 1993), 158–215, esp. 163–77.

CHAPTER THREE

1. *Lederle: A Division of American Cyanamid Company* (New York: American Cyanamid, 1950). A brief history of Davis & Geck will be found on the website of the University of Connecticut: http://www.lib.uconn.edu/online/research/speclib/ASC/findaids/Davisgeck/printableversion/htm (accessed September 30, 2003).
2. During World War II, Lederle's products included typhus, influenza virus, and encephalites (Japanese B) vaccines and gas gangrene antitoxin, pneumonia sera, and blood plasma.
3. For an account of the development of Prontosil, and the role of dye chemists and biomedical researchers at the Elberfeld laboratories, see John E. Lesch, "Chemistry and Biomedicine in an Industrial Setting: The Invention of the Sulfa Drugs," in *Chemical Sciences in the Modern World,* ed. Seymour H. Mauskopf (Philadelphia: University of Pennsylvania Press, 1993), 158–215.
4. Northey studied chemistry at the University of Minnesota, where he was appointed assistant in organic chemistry, 1927–29, and DuPont fellow, 1929–30. He was at DuPont's Jackson Laboratory during September–October 1930, and the Eastern Laboratory in 1930–32. At Calco, he served as group leader divisional chemist until 1942, and assistant director of research, 1942–45. From 1945 to 1950, Northey was administrative director at the Stamford Research Laboratories. He joined the New York office as assistant to the vice president of research in 1950, and was appointed special assistant to the director of laboratories, Pearl River, in 1955.
5. Williams Haynes, "On the Chemical Frontier: The Cyanamid Story," typescript, 1957 (title page marked "Doubleday & Company, Garden City, N.Y."), 135–6, Edelstein Library (hereafter Haynes).
6. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50, 1915–1965* (Bound Brook: American Cyanamid Company, 1965), 11.

7. Sulfapyridine, Ewins and Phillips, Great Britain patent no. 512,145, of 1939, assigned to May & Baker.
8. The vaccine project had also required "acres of land ... covered with large rabbit hutches, occupied by enormous Belgian hares. The animals were the source of antiserum used to treat pneumococcal pneumonia." Will C. Sealy, "My Experience as a Surgical Resident at Duke, 1936–1942," *North Carolina Medical Journal* 62 (2001): 45–51, on 50. William Bell had paid for Duke University's Bell Building, and at the end of the 1930s provided funds for Joseph Beard's studies into vaccines at Duke.
9. Haynes, 136–7.
10. Sulfaguanidine, P. S. Winnek (Stamford), U.S. patent no. 2,218,490, of 1940, assigned to American Cyanamid.
11. Haynes, 137–8.
12. Elmore H. Northey, "The Sulfonamides and Allied Compounds," *Chemical Reviews* 27 (1940): 85-197. This was based on the paper presented to the American Association for the Advancement of Science at the Research Conference in Chemistry, Gibson Island, Maryland, in July 1939. Northey's presentation was later updated and published as *The Sulfonamides and Related Compounds* (American Chemical Society Monographs, no. 106) (New York: Reinhold, 1948). See also, Northey, "Chemical Side of Chemotherapy," *Industrial and Engineering Chemistry* 35 (1943): 829–36, which includes illustrations of Calco plant and discussion of manufacturing processes (834–5), and M. L. Crossley, "The Sulfanilamides as Chemotherapeutic Agents," *Industrial and Engineering Chemistry* 32 (1940), *News Edition* 18, no. 9 (May 10, 1940): 385–88. Information in patent documents, including dates of applications, provides useful indications of research activities into therapeutic agents, and when they were carried out. Northey's name appeared frequently, as the following examples, that supplement those given in the foregoing sources (all assigned to American Cyanamid), show. Elmore Hathaway Northey and Martin Everett Hultquist, "Polysulphanilamidoaromatic, polysulphanilamidoaliphatic and related compounds and a process for making them," U.S. patent no. 2,258,162, October 7, 1941. Application filed April 16, 1938; "The preparation of sulphanilamidopyridines," 2,245,292, June 10, 1941. Application no. 285,968, July 22, 1939 (improved method of preparation: "Compounds of the present invention ... are of importance as chemo-therapeutic agents against bacterial and virus infections and many of them may also be used as dyestuff intermediates"); "N(alkyl, beta-4-morpholylalkyl) aminoalkanol esters," 2,351,833, June 20, 1944. Application 438,115, April 8, 1942 (analogous to the morpholinoalkanol esters); (N′-Alkylpiperazino) alkanol esters, 2,419,366, April 22, 1947. Application 438,116, April 8, 1942; "Morpholinoalkanol esters," 2,475,852, July 12, 1949. Application 438,114, April 8, 1942; Northey and Leonard H. Dhein, "Sulphapyridine processes," 2,322,196, June 15, 1943. Application 435,079, March 17, 1942; Northey and John S. Webb, "Methods of preparing 2-sulfanilamidopyrazine [sulfopyrazine]," 2,444,012, June 22, 1948. Application 535,878, May 16, 1944 ("One step process with excellent yields. Avoids obnoxious solvents and catalysts"); Northey and Paul F. Dreisbach, "The preparation of 4-hydroxyquinolines," 2,478,125/557, August 2, 1949. Application October 9, 1944 (claimed as

intermediates in therapeutical agents, particularly antimalarial remedies.); Northey, "4-mercaptobenzenesulfonamide," 2,356,265, August 22, 1944. Application 453,723, August 5, 1942; Northey, "2-amino 4-methylpyrimidine," 2,378,318, June 12, 1945. Application 405,680, August 6, 1941; Northey, "Formylacetic esters," 2,894,255, February 5, 1946. Application 437,940, April 7, 1942; Northey, "Methods of producing 4-hydroxypyrimidines," 2,417,318, March 11, 1947. Application 604,092, July 9, 1945. By contrast, at Bayer in Germany the sulfonamide studies included thiosemicarbazones, active against tuberculosis. Sulfones, for control of leprosy, were also developed. Alkylation of amino groups was an important reaction in early drug research. In the 1920s and 1930s, Bayer/I.G. Farben chemists converted quinoline and acridine derivatives into antimalarials.

13. "Our Golden Anniversary, 1957," *Bound Brook Diamond* 22, no. 23 (June 13, 1957): 8.
14. For Stokstad see Barry Shane and Kenneth J. Carpenter, "E. L. Robert Stokstad (1913–1995)," *The Journal of Nutrition* 127, no. 2 (February 1997): 199-201.
15. Robert B. Angier, James H. Boothe, Brian L. Hutchings, John H. Mowat, Joseph Semb, E. L. R. Stokstad, Y. Subba Row, Coy W. Waller, Donna B. Cosulich, M. J. Fahrenbach, M. E. Hultquist, Erwin Kuh, E. H. Northey, Doris R. Seeger, J. P. Sickels, and James R. Smith Jr., "The Structure and Synthesis of the Liver *L. casei* Factor," *Science* 103 (1946): 667–69. Folic acid (pteroylmonoglutamic acid) is a form of water-soluble B vitamin. See also Walter Sneader, *Drug Protoypes and Their Exploitation* (Chichester: Wiley, 1996), 421-2.
16. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 19. Calco's sulfaguanidine became a useful research chemical in vitamin studies, as noted by C. A. Elvehjem, at the University of Wisconsin, in "Present Status of the Vitamin B Complex," in *Science in Progress*, ed. George A. Biatsell (New Haven: Yale University Press, 1945), 249–72, on 257. Sulfanilamide acts as a reactant analog when inhibiting the biosynthesis of folic acid through binding to the enzyme responsible for making *p*-aminobenzoic acid.
17. Stanley Scheindlin, "Vicissitudes of a Vitamin: The Rise, Fall, and Rise of Folic Acid," *Modern Drug Design* 4 (2001): 63–66.
18. J. J. Denton, R. J. Turner, W. B. Neier, Virginia A. Lawson, and H. P. Schedl, "Antispasmodics. I. Substituted β-Amino Ketones," *Journal of the American Chemical Society* 71 (1949): 2048–50. See also the three following papers. American Cyanamid's 2-thiouracil was found in 1943 by Edwin B. Astwood at Harvard Medical School to be the most potent inhibitor of thyroid hormone production from among 106 sulfonamides and thiourea derivatives. Astwood announced the first clinical use of thiourea and thiouracil in three patients suffering from overactivity of the thyroid, and this encouraged American Cyanamid to find a safer antithyroid drug than thiouracil. Researchers at Stamford discovered propylthiouracil. In 1945, Stamford's Roblin supplied H. Davenport with Lederle's heterocyclic sulfonamide, thiophen-2-sulfonamide, which turned out to be forty times stronger than other sulfanilamides as a carbonic anhydrase inhibitor. See Sneader, *Drug Protoypes and Their Exploitation*, 597, 608.

19. *Lederle: A Division of American Cyanamid Company*, 14. In 1953, American Cyanamid purchased the Heyden Chemicals antibiotic department.
20. Robert Burns Woodward established the structure in 1952. Pfizer filed a patent for the superior oxytetracycline in November 1949; in the 1960s it was rivaled by Lederle's minocycline. Another American Cyanamid product was Acinitrazole (aminotriazole), originally prepared in 1945 by K. Ganapathi and Krishnasamy Venkataraman at the Haffkine Institute, Bombay. In 1950, American Cyanamid scientists established its antihistomonadal properties. For the evolution of the pharmaceutical industry see Ralph Landau, Basil Achilladelis, and Alexander Scriabine, eds., *Pharmaceutical Innovation: Revolutionizing Human Health* (Philadelphia: Chemical Heritage Foundation Press, 1999).
21. Haynes, 192.
22. Ibid., 50–1.
23. Ibid., 99.
24. For the early history of Beetle, see the lecture by Kenneth M. Chance (managing director, British Cyanides), "The Plastics Exhibition, 1933. Twelth Lecture. Plastics: Urea-formaldehyde Types and Their Uses," *British Plastics and Moulded Products Trader* 5 (1934): 313–18. This journal was founded in 1929 as the official organ of the British Plastic Moulding Trade Association (from 1933, the British Plastics Federation).
25. D. W. F. Hardie and J. Davidson Pratt, *A History of the Modern British Chemical Industry* (Oxford: Pergamon, 1966), 199.
26. W. Blakey, "The History of Aminoplastics. The Sixth Chance Memorial Lecture of the Society of Chemical Industry," *Chemistry and Industry*, July 25, 1964, 1349–57, on 1352. According to Cyril S. Dingley, in his *The Story of B.I.P. (1894–1962)* (Oldbury, Birmingham: British Industrial Plastics Limited, 1962), Beetle Products Co. Ltd was established in 1925 to produce molding powders purchased from British Cyanides Co. Ltd (30–32). Overseas interest led to the "formation of a joint company in the U.S.A. on a 50–50 basis, the American company providing the capital and B.I.P. supplying the 'know how'"(54). Technical information on the Pollopas molding powders was exchanged "with the largest maker in France and the leading producer in Germany."
27. Among the problems encountered were severe corrosion of the reactors. "We found out that this material dicy is violently corrosive on steel when dissolved in anhydrous ammonia and so we began to work in very special stainless steel equipment; but when even in such stainless equipment batches of our melamine were occasionally dark in color, we began to do our studies of corrosion over an even finer scale." The culprit turned out to be thiourea, at 3,000 ppm or more, which had to be reduced by special washing to 50–600 ppm. Victor L. King, "The Technical Department," address to the student trainees of the Calco Chemical Division, American Cyanamid Company, Bound Brook, New Jersey, April 27, 1946, 4. King Papers, MS 429, Dartmouth College Library.
28. Haynes, 100–1.
29. Haynes, 120–1. Before 1940, polymer research at Stamford included guanadines, dicyandiamide, melamine, and melamine-formaldehyde resins.

30. James R. Dudley (American Cyanamid Co., New York), "Urea and Melamine Resins: Press Toward New Goals," *Chemical Industries* 64 (1949): 224–30, 320, esp. 225.
31. See reviews, "Melamine and Its Potentialities in Plastics Manufacture," *British Plastics and Moulded Products Trader* 10 (1939): 27–8, and "Melamine Resins," *British Plastics and Moulded Products Trader* 11 (1939): 326. For an early account of production of the monomer, see P. P. McClellan, "Melamine Preparation," *Industrial and Engineering Chemistry* 32 (1940): 1181–86. See also Anthony S. Travis, "Amino Plastics and the Melamine Story," *Education in Chemistry* 37 (2000): 16–19.
32. Haynes, 102. Haynes's source was Dudley, "Urea and Melamine Resins: Press Toward New Goals."
33. "Over the Shoulder–1940," *Industrial and Engineering Chemistry* 33 (1941): 3–8, on 6.
34. In 1947, American Cyanamid offered: "Laminated Plastics" (melamine-formaldehyde products used in Formica, etc.); "Molded Plastics" (melamine-formaldehydes used for Melmac); and urea-formaldehyde thermosetting resins.
35. Herbert R. Simonds and Joseph V. Sherman, *Plastics Business* (New York: D. Van Nostrand, 1946), 173.
36. See, for example, "Dishing It Out," *Chemical Industries* 66 (1950): 350.
37. Melmac household items have joined the roster of collectible, cultural icons, with an identification and price guide, as described by David Christenson, in "Melmac Was Affordable, Everyday Modernism," *The Old Times* 12 (December 2001).
38. Haynes, 192.

CHAPTER FOUR

1. In 1939, there were 21,000 stockholders, and funded debt consisted of American Cyanamid Company 20-year, 3½ percent sinking fund debentures, dated August 1, 1933 (created to retire $3,960,000 of gold debentures due October 1, 1942, and $1,960,000 of 6 percent purchase money notes due November 1, 1938, and for other corporate purposes); and $6,000,000 American Cyanamid 3½ percent sinking fund debentures, dated October 1, 1937, due October 1, 1957 ("to provide additional working capital and further cash reserves for future requirements"). Capital stock comprised 80,000 American Cyanamid Company Class "A" common shares; 3,620,000 American Cyanamid Company Class "B" common shares (increased from 500,000 to 700,000 shares in January 1929, to 1,600,000 shares on March 27, 1929, to 3,000,000 shares on August 20, 1929, and to 3,620,000 shares on October 4, 1937); and 2,499,996 shares, 5 percent cumulative convertible preferred. "American Cyanamid Company," typescript document, June 5, 1940, SME/AmCy.
2. In 1945, American Cyanamid commissioned artist Robert Brackman to prepare a portrait of Jeffcott that for many years was displayed in the Calco general manager's office. The portrait was presented to the Center for the History of Chemistry (now Chemical Heritage Foundation) on July 29, 1983, by Dr. Frederic Detoro, group

vice president, American Cyanamid, and Dr. Michael Odian, Bound Brook plant manager. "Jeffcott Portrait Presented to CHOC," *CHOC News* 2 (Spring 1984): 4.

3. "Fargo Heads Calco Co.," *Bound Brook Chronicle*, May 5, 1939.
4. J. B. Fisher, "The Industrial Mobilization Plan," *Chemical Warfare Bulletin* 25 (April 1939): 63–68; and "War Resources Board," *Chemical Warfare Bulletin* 25 (October 1939): 159–61.
5. *Fortune*, September 1940, 66–71, 102–6. During 1939, research expenditure was $2 million, considerably less than at DuPont, which was a far larger corporation. See also, William B. Bell, "The Executive and the Technologist: A Proper Understanding between Them," *Industrial and Engineering Chemistry* 32 (1940), *News Edition* 18, no. 5 (1940): 185–90.
6. "New Building Work to Start at Calco," *Bound Brook Chronicle*, November 17, 1939.
7. The power plant is described in W. Rohrhurst (manager, Power Department), "Electricity Comes from High-Level Energy in Steam Going to Process," *Industry and Power* 60 (January 1951): 76–79. In 1941, a 200,000-lb.-per-hour boiler with 5,000-kw turbine was installed, to supplement the three 100,000-lb.-per-hour boilers installed during the 1930s.
8. *What We Do at Calco: A Series of Ten Articles Reprinted from the Plainfield* Courier-News *April 1941* (Bound Brook: Calco Chemical Division, American Cyanamid Company, 1941).
9. Erwin Klingsberg to author, personal interview, February 21, 2001.
10. For Kienle and General Electric's early introduction to polymer chemistry, see Jerome T. Coe, *Unlikely Victory: How General Electric Succeeded in the Chemical Industry* (New York: American Institute of Chemical Engineers/Philadelphia: Chemical Heritage Foundation, 2000), 9–15. See also R. H. Kienle, "Observations as to the Formation of Synthetic Resins," *Industrial and Engineering Chemistry* 22 (1930): 590–94.
11. Among major industrial polymers introduced or discovered in the decade starting 1928 were the first members of the polyvinyl series. They included polybutadiene, polychloroprene (neoprene, for synthetic rubber), polyethylene, polymethyl acrylate, polymethyl methacrylate, polystyrene, polyvinyl acetate, polyvinyl chloride, polyvinyl ether, and polyvinylidene chloride. In contrast to the thermosetting Bakelite and amino plastics, they were thermoplastic, which meant that they could be softened and hardened by heating and cooling. Vinyl acetate resins were introduced during 1928 in the United States as Vinylite A and in Canada as Gelva. Polystyrene came next, following the research at I.G. Farben of Hermann F. Mark and coworkers. It was introduced commercially by I.G. Farben in 1932, and by Dow in 1937, and showed high electrical resistance, and was easy to fabricate. Polyvinyl chloride (PVC) followed in 1932–34. The discovery of polyethylene (polythene) at ICI in England in 1935 arose from a mixture of industrial research into synthetic dyestuffs and reactions carried out under high pressures, and academic research in Holland by Professor Anton Michels of the University of Amsterdam. By the end of 1938, one ton of the new plastic had been manufactured. A full-size plant was completed at the beginning of September 1939,

just as World War II broke out. Polyethylene's properties made it ideal for use in radar equipment. Rohm and Haas in the United States and ICI took great interest in processes for making organic glass. A patent for molded articles made from polymerized methyl methacrylate was filed by ICI in 1931. Production began in 1934, and two years later ICI licensed the process to DuPont, in accord with the terms of a 1929 exchange-of-knowledge agreement between the two firms. The ICI technology was also licensed to Röhm and Haas AG of Darmstadt, whose product was known as Plexiglas from 1936, in return for a license to manufacture cast sheet in Britain. Shortly before World War II, ICI managed to produce sheets of the polymeric material, which it called Perspex. The bulk of production until 1945 was employed in aircraft construction.

12. "Plastics Group," *Chemistry and Industry* 55 (1936): 439–40, on 440; and Roy H. Kienle, "Structural Chemistry of Synthetic Polymerides and Their Films," *Journal of the Society of Chemical Industry (Transactions and Communications)* 55 (1936): 229T–37T. See *American Men of Science*, 9th ed., P., s.v. "Kienle, Roy H."
13. William B. Hardy was, successively, group leader, 1945–49; section leader, dyes research, 1949–53; and manager of chemicals and intermediates research, from 1953, before heading Exploratory Research. His investigations at Bound Brook, where he spent his entire career, led to some impressive innovations. His studies on "Fast Salts, Soluble Vat Dyes (Indigosols), and vat dyes for military applications ... conducted during the period 1941–55, resulted in some products which were manufactured for several years. Later work was done on new processes for aromatic intermediates used for dyes and on isocyanates used for manufacture of polymers. For the last several years at Bound Brook I was responsible for discovery and development of additives for plastics." Hardy to author, email, May 2, 2002.
14. *Calco Diamond* 14 (July 11, 1947): 1.
15. Unpublished typescript reminiscences of C(ornelius) Marsden Vanderwaart, 28, 29 (hereafter Vanderwaart).
16. Cooper received his B.S., majoring in chemical engineering, from Iowa State University, his M.S. from MIT, and his Ph.D. in 1942 from Iowa. At Calco he advanced to chief chemical engineer and then technical director of various sections dealing with inorganic acids, coal-tar refining, aromatic intermediates, rubber chemicals, and pharmaceuticals. In 1952, he joined Colgate-Palmolive, then moved to American Potash & Chemical, prior to cofounding the specialty chemicals firm Antox Inc., in 1968 (renamed Chemanox, Inc., in 1972).
17. James Kenneth Dixon (B.S., majoring in chemistry, Johns Hopkins University, 1926; Ph.D., Yale, 1929) undertook research at Princeton, Berlin, and Yale, prior to joining Calco as research chemist in 1933. Dixon was transferred to Stamford in 1941, and was a group leader with the Manhattan Project during 1944–46. He was appointed American Cyanamid research fellow in August 1963.
18. Vanderwaart, 35.
19. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50, 1915–1965* (Bound Brook: American Cyanamid Company, 1965), 14.
20. Ebel (B.S., Yale, 1938) was a development chemist at Bound Brook during 1945–56,

after which he was a director of process development. He was involved with iminoesters and pharmaceutical and rubber chemicals.

21. During 1941, the Department of Justice filed suits against other American chemical and drug firms, particularly those associated with I.G. Farben, including Winthrop Chemical Corporation. The role of German firms in the United States is described in Mira Wilkins, "German Chemical Firms in the United States from the Late 19th Century to Post-World War II," *The German Chemical Industry in the Twentieth Century*, ed. John E. Lesch (Dordrecht: Kluwer, 2000), 285–321.
22. Phthalic anhydride production in the United States grew from 3,350 tons in 1930 to 29,000 tons in 1940, and would exceed 60,000 tons in 1944, due in no small part to the use of phthalate esters as plasticizers for PVC (polyvinyl chloride). Peter H. Spitz, *Petrochemicals: The Rise of an Industry* (New York: Wiley, 1988), 161.
23. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 14.
24. Ibid.
25. Ibid, 16.
26. *Focus* 15, no. 2 (1994), an American Cyanamid in-house journal, published at Wayne. The first synthetic rubber was made by Bayer in 1910, and known as methyl rubber. Though unsuitable for tires, it was used in the manufacture of accumulator cases for submarines. In the 1920s a butadiene process was investigated in Germany, and a copolymer with styrene, known as Buna S (butadiene-styrene), was developed in 1929. In the 1930s, this was followed with Buna N (butadiene-acrylonitrile). During World War II, the U.S. government funded a massive synthetic-rubber program, from which emerged GR-S, government rubber-styrene; ABS, acrylonitrile-butadiene-styrene; SAN, styrene-acrylonitrile; and SBR, styrene-butadiene rubber. Acrylonitrile for the program was manufactured by American Cyanamid.
27. In 1941, the main resin adhesives were urea-formaldehyde and phenolics. They were soon joined by the new melamine-urea-formaldehyde product, Melurac. W. H. MacHale (Plastics Division, American Cyanamid), "Melurac: A Boil-resistant Durable Adhesive," *Plastics* 7 (November 1944): 40, 111–2. See also Anthony S. Travis, "Modernizing Industrial Organic Chemistry: Great Britain Between Two World Wars," in *Determinants in the Evolution of the European Chemical Industry, 1900–1939: New Technologies, Political Frameworks, Markets and Companies*, ed. Anthony S. Travis, Harm G. Schröter, Ernst Homburg, and Peter J. T. Morris (Dordrecht: Kluwer, 1998), 171–98, on 183–4. Rohm and Haas produced a strong plywood adhesive called Tego, based on German technology, though requiring a hot press for its application, as well as liquid urea-formaldehyde resins through its associated Resinous Products and Chemical Company. Sheldon Hochheiser, *Rohm and Haas: History of a Chemical Company* (Philadelphia: University of Pennsylvania Press, 1986), 41–51.
28. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 16.
29. Ibid.
30. Ibid., 17.
31. Ibid.
32. Richard L. Tuve, "Development of the U.S. Navy 'Shark Chaser' Chemical Shark Repellent," in *Sharks and Survival*, ed. Perry W. Gilbert (Boston: D. C. Heath,

1963), 455–64. Williams Haynes, "On the Chemical Frontier: The Cyanamid Story," typescript, 1957 (title page marked "Doubleday & Company, Garden City, N.Y."), 123, 141–2, Edelstein Library (hereafter Haynes). The shark repellent was a polyethylene glycol wax (Carbowax) containing the nigrosine colorant and copper acetate.

33. Doug Stanton, *In Harm's Way: The Sinking of the USS* Indianapolis *and the Extraordinary Story of Its Survivors* (London: Bantam Press, 2001), 166.
34. I.G. Farben assets were seized in both the United States and Mexico. In June 1942, the U.S. Alien Property Custodian took control of General Aniline and Film (GAF), under the Trading With The Enemy Act. The U.S. drug firms Sterling and Winthrop, with former close connections to I.G. Farben, objected to the Mexican takeover by American Cyanamid, as did other vested interests, and this venture was dropped.
35. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 17.
36. Vanderwaart, 30.
37. Ibid., 36.
38. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 14.
39. *Chemical Industries* 52 (1943): 222. In 1945, Waitt was appointed head of the Chemical Warfare Service, which in 1946 became known as the Chemical Corps. Waitt had studied chemistry at MIT, where during 1925–27 he undertook research at the Research Laboratory of Applied Chemistry. For biographical details see *The Chemical Warfare Service in World War II: A Report of Accomplishments* (New York: Reinhold Publishing Company for the Chemical Corps Association, 1948). The MIT Research Laboratory of Applied Chemistry was closed down in 1934, at a time when the chemistry department increasingly emphasized basic science, and most large chemical firms had their own research departments.
40. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 15. During the war, the format of the *Calco Diamond* was changed to that of a tabloid newspaper that appeared weekly instead of monthly.
41. *Chemical Industries* 54 (1944): 110; Isaiah Von to author, email, May 16, 2001. Only organic pigments were made at Bound Brook. The United Color & Pigment Division's inorganic pigment processes were taken up at the postwar Willow Island facility; products included iron blue, chrome yellow, and chrome orange.
42. "Patent Agreements" and "Good Morning, Have You Been Indicted?" editorials, *Industrial and Engineering Chemistry* 34 (1942): 1416.
43. For 1942, federal, foreign, and excess profit taxes totaled $15 million. In 1941 American Cyanamid's net profit, after taxes of $11,457,636, was $6,347,398.
44. Thomas Derdak, ed., *International Directory of Company Histories* (Chicago: St. James Press, 1988), vol. 1, 300–2, on 301. *Chemical Industries* 50, no. 5 (May 1942), unnumbered "chem-o-gram" insert containing late news. In June 1942, American Cyanamid was one of a number of firms accused of illegal price-fixing in inorganic acids. Britain's ICI was named among the defendants in this and similar cases. In sharp contrast to the United States, British lawmakers showed little concern over the arrangements between chemical firms, which were seen to be more in keeping with technical exchanges than market sharing. In any event, with the outbreak of World

War II in 1939, ICI's arrangements with I.G. Farben were scuttled. In the United States, editorials in *Chemical Industries* and elsewhere questioned the extent to which sectors of the American chemical industry were singled out for profiteering, price-fixing, and antitrust actions. There was support for legislation that would enable the War Production Board, created early in 1942, rather than the Department of Justice to decide on which firms should be indicted. See, for example, "Van Nuys' Bill: A Step in the Right Direction," *Chemical Industries* 50 (1942): 755. Under Thurman W. Arnold, from 1938 to 1944 assistant attorney general, Antitrust Division, Department of Justice, the department pursued some 180 antitrust cases during 1938–42. While this effort, coordinated with the Temporary National Economic Committee, was relaxed later in the war, it was revived late in 1944. See U.S. Congress, Senate, Committee on Military Affairs, *Cartel Practices and National Security, Hearings before a Subcommittee of the Committee on Military Affairs*, 78th Cong., 2nd Sess., 1944. Technology sharing through patent pools and cartel formation involving American and European firms is discussed in David A. Hounshell and John Kenly Smith Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980* (Cambridge: Cambridge University Press, 1988), 190–209 (including with I.G. Farben and ICI), and 346–7 (antitrust cases, 1938–42) (hereafter Hounshell and Smith); and William J. Reader, *Imperial Chemical Industries: A History*, 2 vols. (London: Oxford University Press, 1970), vol. 2, *The First Quarter-Century 1926–1952.* Reader describes how for the first time a non-American corporation was investigated for activities outside the United States (428–44). The petrochemical firms did not escape the attentions of antitrust investigators. Universal Oil Products Company, a research and development firm owned by a consortium of seven oil companies that shared patents through the system of cross-licensing, was indicted for patent infringement in 1944, and was also associated with obstructing justice through bribery. Later in the year its stock became the property of the new Petroleum Research Fund, administered by the American Chemical Society. See Charles Remsberg and Hal Higdon, *Ideas for Rent: The UOP Story* (Des Plaines, Ill.: UOP, 1994); Basil Achilladelis, "History of UOP: From Petroleum Refining to Petrochemicals," *Chemistry and Industry*, April 19, 1975, 337–44; and Justin W. Collat, "UOP and PRF: How the Petroleum Research Fund Came to Be," *Chemical Heritage* 12 (Summer 1995): 1, 5–6.

45. From American Cyanamid annual report 1942, quoted in *Cyanamid at 85* (Wayne, N.J.: American Cyanamid, Public Affairs Division, 1992), 4, special section of *Focus* 13, no. 3 (1992). For the entry of women into the chemical industry during 1943, see Hannah Garry, "Chemical Womenpower," *Chemical Industries* 52 (1943): 445–49.
46. "108th Meeting American Chemical Society," special issue of *The Indicator* 25 (September 1944).
47. "War Production. Calco Chemical Company," Bridgewater Township Meeting Minutes, December 30, 1940. "A petition was presented by Mrs. Pierrot and Mr. Butz with over 200 signers, protesting the coming in of colored people to live in the barracks recently built by the Chemical Company. They also stated it would be detrimental to their property values ... Mr. Devine later entered the meeting and stated that Mr. McMurray [of Calco] had stated they were going up in Pennsylvania

to hire men and they would occupy these rooms only until they found rooms in towns. He also stated the [barracks] permit was only a temporary one and it was for the duration and three months after which time it must be demolished."

48. DuPont's organic chemicals (Orchem) division displayed considerable anti-Semitic tendencies, despite the recommendation of the Executive Committee that one or two outstanding refugee German-Jewish chemists be taken on. However, even in the 1930s there were Jewish research chemists at DuPont, since, as at Bound Brook, firms in which Jews were involved had been acquired. Also, at DuPont, whether or not Jewish chemists were employed depended on the divisional and departmental heads. See Hounshell and Smith, 296.
49. Jay Leavitt recalls that "there were other Jews in the plant area, but as far as I know, I was probably the first of several in research." Leavitt states that the reason he was hired by Lecher "was because I had done my Ph.D. with Linstead and the first project was his [Lecher's] last stab at the phthalocyanine area. However, I never did work on the phthalo blue effort but was first assigned to vat dyes: brilliant orange RK, dibromoanthanthrone." Jay Leavitt to author, email, May 20, 2002. From 1961, Leavitt served as editor of the dyes section of *Chemical Abstracts.* See also *American Men and Women of Science*, 19th ed., s.v. "Leavitt, Julian Jacob."
50. Isaiah Von adds to the story of how Jewish chemists came to Calco: "As an aside to illustrate the degree of antisemitism in those days, I met Jay [Leavitt] when we worked together along with several other workers on explosives research in a secret project at the University of Pennsylvania. In 1944 Jay decided to look for another job. At the same time another chemist, a gentile, had the same idea. They both went to the American Chemical Society convention, which had 'clearing houses' where employers and candidates were brought together for interviews. The gentile candidate who in my opinion was not as capable as Jay, but who came from a good school (U. of Illinois), got 33 interviews according to Jay. Jay got 4, one of which was Calco." Isaiah Von to author, email, May 16, 2001.
51. Von remarks: "There is no doubt that there was antisemitism among the large chemical companies before and during the war. This included Cyanamid, except for the Calco Division. I know of only one [Jewish] chemist who worked for a major company (National Aniline), Maurice Fleischer, who was a friend of my father." Two notable Jewish chemists in the New Jersey pharmaceutical industry were Max Tischler, hired by Merck in 1937, and Erwin Schwenk, a director of research at Schering. Among the Jewish entrepreneurs selling out to American Cyanamid was Mark Weisberg, who sold his Textile Chemical Co. of Providence, Rhode Island, to the corporation in 1929. He then engaged in other activities.
52. Victor L. King, "The Technical Department," address to the student trainees of the Calco Chemical Division, American Cyanamid Company, Bound Brook, New Jersey, April 27, 1946, 1. King Papers, MS 429, Dartmouth College Library.
53. Norman A. Shepard, "The Chemical Industry," in *Industrial Science: Present and Future*, arranged by Allen T. Bonnell, Ruth C. Christman, ed. (Washington, D.C.: American Association for the Advancement of Science, 1952), 44–57, on 47. Shepard had taught at Yale, then directed chemical research at Firestone Tire and Rubber Co. prior to joining American Cyanamid's Stamford laboratories, where he became

director of technical services. Among his publications was "A Guide to Harmonious Collaboration between Technical Service and Research," *Chemical Industries* 57 (1945): 73–4.

54. Krishnasamy Venkataraman, *The Chemistry of Synthetic Dyes*, 2 vols. (New York: Academic Press, 1952), vol. 1, 13. Both the United States and Britain manufactured more dyes than Germany during 1946–52.
55. Herbert Levinstein, "Du Pont Research," *Chemistry and Industry*, May 12, 1945, 148.
56. During April to mid-June 1947, DuPont and GAF representatives undertook an extensive survey of German intermediate and dyestuff technology and research for the Technical Industrial Intelligence Division, U.S. Department of Commerce, published as the three-volume FIAT Final Report, no. 1313, PB 85172, *German Dyestuffs and Dyestuffs Intermediates, Including Manufacturing Processes, Plant Design, and Research Data* (Washington, D.C.: Office of Military Government for Germany (U.S.)/Field Information Agency, Technical, February 1, 1948). According to H. A. Lubs (DuPont), ed., *The Chemistry of Synthetic Dyes and Pigments* (American Chemical Society Monograph Series) (New York: Reinhold, 1955): "This was the broadest and most recent of the numerous Allied reports on the pre-World War II German dye industry. It was written by the last American team to visit Germany for this purpose" (701).
57. Victor L. King: "The Chemical Industry in Europe," paper presented at Bound Brook, December 1946. King Papers, MS 429, Dartmouth College Library. For the impressions of a British technical specialist, including of travel conditions, see "Technical Investigations in Germany: Some Observations by a Recent Investigator," *Chemistry and Industry*, September 27, 1947, 587–89.
58. King: "The Chemical Industry in Europe," 4.
59. Ibid., 4–5
60. Ibid., 6.
61. For the technical organization at I.G. Farben, the reader is referred to Peter J. T. Morris's study, "Ambros, Reppe and the Emergence of Heavy Organic Chemicals in Germany, 1925–1945," in *Determinants in the Evolution of the European Chemical Industry, 1900–1939*, ed. Travis, et al., 89–122. See especially the figure of technical and management committees at I.G. Farben (106).
62. King, "The Chemical Industry in Europe," 10.
63. Ibid, 13, 17.
64. Ibid., 20. For another American impression of German chemical industry, see Spitz, *Petrochemicals: The Rise of an Industry*, 1–17, 42–52. Allied investigators into German chemistry were particularly interested in the new methods of organic synthesis based on Reppe chemistry, the Fischer–Tropsch process, and the Roelen or OXO synthesis that converted olefinic products from the Fischer–Tropsch process into long-chain alcohols.
65. David H. Wilcox Jr., "Moses Leverock Crossley," in *American Chemists and Chemical Engineers*, ed. Wyndham D. Miles (Washington, D.C.: American Chemical Society, 1976), 102–3. Williams, a 1929 chemistry graduate from Worcester Polytechnic Institute, was at Allied Chemical's patent department before

joining American Cyanamid, where he worked on sulfa drugs, and, later at Lederle, on aureomycin and other antibiotics.

66. Peter J. T. Morris "Vom Buna zum Hi-Fax: Technologietransfer von Deutschland in die Vereinigten Staaten auf dem Gebiet der Polymere (1925–1960)," and Raymond G. Stokes, "Flexible Reaktion: Die Bedeutung des Technologietransfers für die deutsche Chemieindustrie (1925–1961)," in *Technologietransfer aus der deutschen Chemieindustrie (1925–1960)*, ed. Rolf Petri (Berlin: Duncker & Humblot, 2004).
67. Norman A. Shepard, "German Chemical Industry: Capacity High, Recovery Slow," *Chemical Industries* 62 (1948): 50–52. One German process for which American Cyanamid's Chemical Construction Corporation acquired the U.S. rights was for conversion of natural gas and oxygen into acetylene using special burners. This was important for the acrylonitrile process operated at Fortier, near New Orleans, Louisiana. The earlier Warners plant relied on ethylene oxide.
68. "Association of British Chemical Manufacturers," *Chemistry and Industry*, October 27, 1945, 334.
69. Raymond G. Stokes, *Opting for Oil: The Political Economy of Technological Change in the West German Chemical Industry, 1945–1961* (Cambridge: Cambridge University Press, 1994), 40–47.
70. Howard W. Ambruster, *Treason's Peace: German Dyes and American Dupes* (New York: Beechhurst Press, 1947).
71. For reconstruction in Germany, see Raymond G. Stokes, *Divide and Prosper: The Heirs of I. G. Farben under Allied Authority, 1945–1951* (Berkeley: University of California Press, 1988), which also analyzes policy differences in the French, British, and American sectors. See also Stokes, "Technology and the West German *Wirtschaftswunder*," *Technology and Culture* 32 (1991): 1–22.

CHAPTER FIVE

1. Peter H. Spitz, *Petrochemicals: The Rise of an Industry* (New York: Wiley, 1988), provides useful overviews of technical developments in the international chemical industry during the postwar period. See in particular chapter 9.
2. "Gigantic Building Project for Calco," *Bound Brook Chronicle*, November 15, 1945.
3. Allen received his M.S. from Columbia University, Stevens Institute, in 1944, and Ph.D. from Rutgers University in 1952. See *Research News*, September–October 1963, 16. At Bound Brook, Allen was research chemist during 1945–56, group leader, 1956–61, senior research scientist, 1961–63, research associate, 1963–66, and research fellow, 1966–67. In 1967, he joined Lehigh University.
4. Andrew M. Fairlie, *Sulfuric Acid Manufacture* (American Chemical Society Monograph Series no. 69) (New York: Reinhold, 1936), 411–12.
5. "Calco Librarian Honoured," *Chemistry and Industry*, August 24, 1946, 317.
6. *Calco Diamond* 14 (July 11, 1947): 1.
7. Unpublished typescript reminiscences of C(ornelius) Marsden Vanderwaart

(hereafter Vanderwaart), 30. Harvey W. Whitten Jr. was for many years group leader in Process Research. In 1968, he joined the Process Engineering Group.

8. Ibid., 29.
9. "Profiteering in Chemicals," *Chemical Industries* 62 (1948): 39. From September 1945, Pfister's assistant was James Naylor, who since 1938 had managed the Providence, Rhode Island, sales office.
10. Production of the first Pepton began in 1948. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50, 1915–1965* (Bound Brook: American Cyanamid Company, 1965), 18. Pepton 22 and Pepton 65 were "added to rubber to aid mastication or plasticizing of this tough elastomer so that it could be easily processed into finished goods. Accelerators are added to the mixture of rubber, sulfur and fillers to speed … vulcanization … Antioxidants [tertiary-butyl phenol derivatives] 2246 and 2425 are added to the mixture to insure the long life of the product and to prevent discoloration and staining of white and light colored rubber articles."
11. H. B. H. Cooper and W. C. McIntire, "Flexibility in Pilot Plant Operations," *Industrial and Engineering Chemistry* 44 (1952): 2814–18. The pilot plant "started operation in 1945 in a steel and concrete building having a floor area of about 12,000 square feet (115 x 108 feet) with a monitor-type roof over the center two bays with a fixed balcony at a height of 13 feet along the two outside bays."
12. "The important anthrimide-carbazole group of vat dyes was described, with attention to Calco's contribution in forcing anthrimide formation between an alpha chlor and beta amino anthraquinone by use of a catalyst composed of copper and an excess of iodine, and giving the excellent Calco Copper Brown … The chemistry of some of the highly condensed quinone vat dyes was next sketched. Using the cases of Vat Golden Yellow GK and Brilliant Orange RK for examples, the use of naphthalene chemistry was brought out. The contributions of Scholl in synthesizing several dyes by Friedel–Crafts benzoylations of hydrocarbons like pyrene and perylene, especially in proving structure, were noted." Wendell P. Munro, "Talk before Calco Chief Chemists' Club, September 17, 1948, Recent Chemistry of Anthraquinone (Author's Summary)," SME/AmCy.
13. Isaiah Von to author, email, May 6, 2001. Other producers of soluble vat dyes included National Aniline (Solvats) and GAF, in whose laboratories the American Cyanamid process was modified.
14. *Dyestuff Data for Paper Makers* (Bound Brook: American Cyanamid, Calco Chemical Division, 1952). The first (Heller & Merz) edition of this publication appeared in 1924, and a revised version was produced in 1935.
15. Munro explained that the "batch-wise phthalic anhydride-benzene synthesis of anthraquinone by Gibbs and Wohl in 1917 made a cheap high quality material available. Only recently, a patent to Socony-Vacuum describes a continuous vapor phase process, using an activated alumina-silica catalyst." Munro also discussed the "orientation of entering nitro and sulfonic groups, with and without mercury catalyst [for the important 1-sulfonic acid]," and pointed out that "the mordant, hydroxylated dyes were largely superseded now. To some extent also were the simple acylamino anthraquinones. However, some triazine derivatives of amino

anthraquinones have excellent characteristics, e.g. Cibanone Red G, Calco Fast Yellow." Munro's talk concluded with a list of special uses for anthraquinone compounds: "gasoline colors, colored signaling smokes, for stabilizing transformer oils, as printing assistants, in the manufacture of hydrogen peroxide in Germany (ethyl anthraquinone), and as a color reagent for the analysis of minute amounts of boron in steel." Munro, "Talk before Calco Chief Chemists' Club." Socony (Standard Oil Company of New York) was created by the separation from Standard Oil Company (New Jersey) of its subsidiaries. In 1931, Socony amalgamated with another Standard Oil affiliate, Vacuum Oil Co., to create Socony-Vacuum Corporation, forerunner of Socony Mobil Oil Co., Inc. (1955), later Mobil Oil Corp. (1966), then Mobil Corp. (1976), acquired by Exxon, successor to Standard Oil Company (New Jersey), in 1999. Petroleum-based phthalic anhydride, however, was not commercially viable until the 1950s. Selden was still the largest U.S. supplier in 1949. The main uses were in manufacture of alkyd resins, phthalate esters, vat dyes and phthalimide for phthalocyanine pigments. See Herman W. Zabel, "Phthalic Anhydride: Twenty-fold in Twenty Years," *Chemical Industries* 65 (1949): 573-75.

16. Anthracene was available for a time from the distillation process used to extract coal-tar carbazol, required as an insecticide, while considerable amounts of anthraquinone were imported around 1950, mainly from Belgium.
17. Erwin Klingsberg to author, personal interview, February 21, 2001.
18. Charles L. Harness, *The Catalyst* (New York: Pocket Books, 1980). Also involved with patents at Bound Brook from 1946 was research chemist E. Janet Berry (Ph.D., Purdue, 1946), who in 1952 received a law degree from New York University Law School, and embarked on a successful career as a patent attorney. Another Bound Brook organic chemist (during 1951–56) to enter the legal profession is Pauline Newman (Ph.D., Yale), currently judge of the United States Court of Appeals for the Federal Circuit.
19. "Charles L. Harness: I Did It for the Money," interview by Charles N. Brown in *Locus* 41 (December 1998): 6, 73. Harness obtained his B.S., majoring in chemistry, in 1942, and law degree in 1946, both from George Washington University. During 1941–47 he was employed by the U.S. Bureau of Mines. He was at American Cyanamid during 1947–53, and then at W. R. Grace & Co. during 1953–81.
20. Erwin Klingsberg, "Qualitative and Quantitative Analysis of Vat Dyes by Paper Chromatography," *Journal of the Society of Dyers and Colourists* 70, no. 12 (December 1954): 563–67.
21. Jay Leavitt to author, personal interview, February 28, 2001. The same type of imitative research was carried out at British firms. See Maurice R. Fox, *Dye-Makers of Great Britain, 1856–1976: A History of Chemists, Companies, Products and Changes* (Manchester: ICI, 1987), 204.
22. This was typical of approaches throughout the dye industry. Thus at ICI in England the Dyestuffs Division, aided by the Exploratory Research Section, developed mass spectrometry from 1947 for analysis of competitors' dyes. See John H. Beynon, "The Eternal Triangle: Research, Universities and Industry," *Chemistry and Industry*, March 17, 1979, 175–82.
23. Victor L. King, "The Technical Department," address to the student trainees of the

Calco Chemical Division, American Cyanamid Company, Bound Brook, New Jersey, April 27, 1946, 7. King Papers, MS 429, Dartmouth College Library.

24. The optical bleaches are based on fluorescent dyes. They are also known as fluorescent, or optical, whitening agents. Other names are colorless dyes, and brightening agents.
25. A summary of research in this area is Robert S. Long, "Fluorescent White Dyes," in *Proceedings of the Perkin Centennial 1856–1956. Commemorating the Discovery of Aniline Dyes*, ed. Howard White Jr. (sponsored by the American Association of Textile Chemists and Colorists, 1956), 411–22. At Bound Brook, new products of the triazine, amide, and azole classes were investigated by Eberhart, Lecher, Scalera, C. A. Sears, and Long. Eugene Allen also undertook instrumental evaluation of brighteners.
26. The many carefully designed swatch books and dyeing manuals produced around this time included *American Cyanamid Co., Direct Colors on Viscose Rayon*, and *American Cyanamid Co., Chrome Colors for Wool Stock* (Bound Brook: Calco Chemical Division, American Cyanamid Co. [ca. 1950]). The former covered Calcomine, Calcodur, and Calcoform (after-treatment with formaldehyde) dyes. The latter contained 144 dyed samples, accompanied by instructions for dyeing, and discussion of loose wool coloration by top chrome, metachrome, and chrome bottom processes.
27. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 27.
28. *MCA 1872–1972: A Centennial History* (Washington, D.C.: Manufacturing Chemists' Association, 1972), 71-2.
29. Victor L. King, "The Chemical Industry at Home and Abroad," manuscript for lecture, dated December 1953, 4. King Papers, MS 429, Dartmouth College Library. The lecture was given at a rotary meeting held in Bridgeville, Pennsylvania, on December 3, 1953. Lederle Laboratories (India) Ltd began manufacture of pharmaceuticals in 1953.
30. In 1936, Venkataraman was appointed professor of chemical technology and director of Bombay University's Department of Chemical Technology. In 1957 he became director of the Indian National Chemical Laboratory, where he established divisions of organic intermediates and dyes, essential oils, and fine chemicals. During 1970–78 he edited a further eight volumes in the same series, and also published a study dealing with the analytical chemistry of synthetic dyes. See obituary by E. H. Daruwalla, *Journal of the Society of Dyers and Colourists* 98, no. 2 (February 1982): 67.
31. In September 1947, the British Ministry of Health permitted the import of folic acid, which created a significant export market.
32. American Cyanamid was the sole American manufacturer of cyanuric chloride, 2,4,6-trichloro-1,3,5-triazine, at the Warners facility. Pilot-plant production commenced in 1949, and manufacture began in the mid-1950s. Cyanuric chloride is structurally related to melamine, and was an important product used in dye manufacture, particularly in linking together different types of dyes and, from 1956, in the synthesis of fiber-reactive dyes.

33. *Calcodur Resin Fast Dyes* (Bound Brook: American Cyanamid, Dyestuff Department [1954]).
34. Isaiah Von and William Baptist Hardy, "Benzanthrone anthraquinone acridines for dyestuffs," U.S. patent no. 2,993,901, July 25, 1961; filed June 8, 1953.
35. V. E. Atkins, "Calco Notice," November 17, 1953, Bound Brook Memorial Library.
36. Baxter S. Blitz and J. Kondrick, "How a Plant Maintenance Organization Functions," *Industry and Power* 60 (1951): 108–11. This describes maintenance at Willow Island, which was almost identical to the situation at Bound Brook, on which it was based.
37. Victor L. King, "The Value of Cost Statements to the Technical Dept.," a talk to Calco accountants, May 20, 1948, 4–5. King Papers, MS 429, Dartmouth College Library. DuPont was an early industrial leader in the introduction of cost-accounting practices.
38. Victor L. King, "Some Means that Contribute to the Successful Management of a Chemical Manufacturing Operation," a talk to chemical engineers, accountants, and production men at Lederle Laboratories, January 12, 1950, 2. King Papers, MS 429, Dartmouth College Library. An earlier version of this paper was given to manufacturing supervisors of E. R. Squibb & Sons on November 23, 1948.
39. K. H. Ferber, "The Science of Color," *Dyestuffs* 41, no.1 (March 1955): 1–8. *Dyestuffs* was published by the National Aniline Division of Allied Chemical & Dye Corporation.
40. Arthur C. Hardy, "History of the Design of the Recording Spectrophotometer," *Journal of the Optical Society of America* 28 (October 1938): 360–64.
41. Frank J. O'Neil, "Twenty-five Years of Color Control," in *Proceedings of the Perkin Centennial 1856–1956*, 123-30. For a more recent survey of the status of color measurement, including historical developments, see "Color Measurement: Visual and Instrumental," *Textile Chemist and Colorist* 22, no. 8 (March 1990): 18-22.
42. Royer's interests included dyes, intermediates, microscopy, spectroscopy, microchemistry, dye application and dyeing phenomena, and photography. Brief biographical details appear in *Review of Textile Coloring and Finishing* (Calco Technical Bulletin, no. 818) (1950), reprinted from *American Dyestuff Reporter*, December 11, 1950. Stearns, who served at Calco as physicist during 1933–45, and chief physicist 1944–45, was awarded the Ph.D. from Rutgers University in 1945 for "A Study on the Relation between Structure and Fastness to Light of Mono-Azo Dyes." He was assistant to the director of physics research during 1945–51, manager of product improvement, Dyestuff Department, 1952–54, and then moved to the Chicago office as assistant manager, mid-western territory. In 1952 he was president of the Inter-Society Color Council. His research interests covered the phase rule, spectroscopy and instrumentation, photochemistry, the optical properties of pigments, and instrumentation as applied to chemical processes. The *American Dyestuff Reporter* was the journal of the American Association of Textile Chemists and Colorists from 1917 until 1967, when it was sold to Herbert A. Stauderman. From 1968, the journal of the association was the *Textile Chemist and Colorist*. In 1999, *American Dyestuff Reporter* was merged with *Textile Chemist and Colorist*.
43. I. H. Godlove was at the Munsell Research Laboratory, Baltimore, during 1926–30,

then at the Color Service Laboratories, Washington, D.C., until 1935, when he joined DuPont, at Wilmington, from where he moved to GAF (1943–54). See obituary, *Journal of the Optical Society of America* 44 (November 1954): 887.

44. E. I. Stearns, "Dyeing for a Living, Part IV," *Dye-Chemlines* 13, no. 5 (October 1968): 1, 4.
45. E. I. Stearns, "What's New in Spectrophotometry: Progress of Spectrophotometry in the Textile Industry," paper presented to a combined meeting of the Philadelphia Section of the American Association of Textile Chemists and Colorists and the Philadelphia-Wilmington Colorists, Philadelphia, April 13, 1951. This includes a complete bibliography, and appendix that indicates the type of calculation involved in early spectrophotometric work. Reprinted by American Cyanamid from *American Dyestuff Reporter.*
46. See, for example, E. I. Stearns, "Applications of Ultraviolet and Visible Spectrophotometric Data," in *Analytical Absorption Spectroscopy: Absorptimetry and Colorimetry*, ed. M. G. Mellon (New York: Wiley, 1950), 306–438. This includes clinical applications, notably the 1938 work of Hamblin and Mangelsdorff (see chapter 9). For Barnes and the American Cyanamid connection with Perkin-Elmer, see Yakov M. Rabkin, "Technological Innovation in Science: The Adoption of Infrared Spectroscopy by Chemists," *Isis* 78 (1987): 31–54. American Cyanamid had originally intended to manufacture spectrophotometers, but lacking experience in optical systems it turned to Perkin and Elmer, whose firm became a major U.S. manufacturer, and principal competitor of Beckman.
47. R. Bowling Barnes, Robert S. McDonald, Van Zandt Williams, and Richard F. Kinnaird, "Small Prism Infra-Red Spectrometry," *Journal of Applied Physics* 16 (1945): 77–86.
48. A. G. Jones, *Analytical Chemistry: Some New Techniques* (London: Butterworths, 1959), 1.
49. Stearns's interest in instruments contributed to scientific knowledge in other ways. In September 1951, when the American Chemical Society diamond jubilee meeting and the 12th International Congress of Pure and Applied Chemistry were held in New York, American Cyanamid sponsored four lecture-demonstrations on "Chemistry on a Cosmic Scale" at the Hayden Planetarium of the American Museum of Natural History. One was given by Bound Brook chemist S. I. Gale, Fellow of the Royal Astronomical Society, London, and another by Stearns, who discussed "The Contribution of Physical Chemistry to the Astronomer."
50. E. I. Stearns, *The Practice of Absorption Spectrophotometry* (New York: Wiley-Interscience, 1969).
51. For instrumentation at Stamford, see R. P. Chapman, "Organization and Functions of an Analytical and Testing Group," *Chemical Industries* 65 (1949): 718–21.
52. Robert C. Hirt, Frank T. King, and R. G. Schmitt, "Graphical Absorbance-Ratio Method for Rapid Two-Component Spectrophotometric Analysis," *Analytical Chemistry* 26 (1954): 1270–73. Data were provided for nitrophenols, nitrobenzene, aniline, and mixtures of melamine, ammeline, and trimethylolmelamine (the latter three compounds were relevant to production of amino resins).
53. Ibid., 1272. A further example of American Cyanamid expertise in instrumental

analysis is the book co-authored by Bound Brook research fellow Dr. William Seaman and Johns-Manville research chemist Frank M. Biffen, *Modern Instruments in Chemical Analysis* (New York: McGraw-Hill, 1956).

54. For an application of the dyeometer, see O. W. Clark and H. R. McLeary, *Vat Dyeing: Importance of Initial Exhaustion Rate* (Technical Bulletin no. 810, Calco Technical Division) (Bound Brook: American Cyanamid Co., 1949).
55. See, for example, G. L. Buc, R. H. Kienle, L. A. Melsheimer, and E. I. Stearns, "Phenomenon of Bronze in Surface Coatings," *Industrial and Engineering Chemistry* 39 (1947): 147–54. The accompanying colored photographs were prepared by Royer and Maresh.
56. The society is now known as the New York Society for Coatings Technology. For its history until 1969, see William J. Greco, "Through the Years: A History of the New York Society for Paint Technology, Delivered at the April 1st Meeting, Commemorating the 50th Anniversary of The New York Society [1969]," available on the society's website, http://www.nysct.org (accessed September 9, 2003).
57. King, "Some Means that Contribute to the Successful Management of a Chemical Manufacturing Operation," 2–3. See also W. B. Heinz (Calco Engineering Department) and W. T. Henrickson (Calco Mechanical Department), "Instrumentation and Automatic Control," *Chemical Industries* 50 (1942): 210–13.
58. Cooper and McIntire, "Flexibility in Pilot Plant Operations," 2814.
59. Vanderwaart, 36.

CHAPTER SIX

1. Gerard A. Forlenza to author, telephone, April 23, 2002.
2. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50, 1915–1965* (Bound Brook: American Cyanamid Company, 1965), 18. Sidney Moody was Calco general manager from February 1, 1945 to December 31, 1953. Previously, from 1937, he was a department sales manager, and from August 1943 had taken on the responsibilities of a general manager. He was a vice president of American Cyanamid during 1946–55.
3. Paden obtained his Ph.D. in 1936 from Wisconsin, and joined the Stamford Research Laboratories on their opening in 1937. In 1950, he was appointed director of the organic and physical laboratories. Elmore Northey was appointed technical director, Fine Chemicals Division, New York.
4. Victor L. King, "The Chemical Industry at Home and Abroad," lecture given at a rotary meeting, held in Bridgeville, Pennsylvania, on December 3, 1953, 3. King Papers, MS 429, Dartmouth College Library. Around this time, King also prepared the paper "Chemicals: The Job Makers," as a contribution to Chemical Progress Week, sponsored by the Manufacturing Chemists' Association, May 17–22, 1954.
5. V. E. Atkins joined Calco at the end of 1935, after several years at Goodrich and then at a manufacturer of rubber products. He had served as Bound Brook works manager and manager of manufacturing.

6. "Million Dollar Expansion Project Announced by Bound Brook Cyanamid," *Bound Brook Chronicle*, September 22, 1955.
7. It was probably around 1955 that, as Von recounts, the methylation step for Jade Green began to employ the highly toxic dimethyl sulfate: "The only place in which we used dimethyl sulfate in vat dyes was in the final step in Jade Green. Initially we used methyl toluene sulfonate, which was more expensive. Our Safety Department refused to let us use dimethyl sulfate without building a room around the methylation equipment which would have super ventilation. This would have cost us most of the savings. We learned what Toms River [CIBA] and DuPont did, and did the same. We installed a loading station with weigh scale on a platform outside and ran a welded pipe through the wall directly to the kettle. This worked fine for the next 25 years."
8. Isaiah Von to author, various emails, August 2001.
9. Fordemwalt, whose Ph.D. was in physical chemistry (Iowa, 1940), joined Calco as a research chemist in 1949, and in 1950 was appointed assistant manager of dyes research.
10. *The Perkin Centennial, 1856–1956, General Program. Mauve–The Key to the Rainbow. The Waldorf-Astoria, New York; Week of September 10, 1956* (American Association of Textile Chemists and Colorists, 1956); and contributions to Howard White Jr., ed., *Proceedings of the Perkin Centennial 1856–1956. Commemorating the Discovery of Aniline Dyes* (Sponsored by the American Association of Textile Chemists and Colorists, 1956).
11. Jay Leavitt to author, various emails, April and May 2001.
12. "Favorable Year Forecast for Cyanamid to Mark Its 50th Anniversary," *Bound Brook Chronicle*, January 3, 1957.
13. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 36.
14. The inflammable gas phosphine, made from red phosphorus, was, according to Jay Leavitt, "used primarily to make the flame retardant THPC (tetrakishydroxymethylphosphonium chloride) by reaction with formaldehyde and HCl. We also made the sulfate and the oxalate. By reaction with olefins it was converted to tributyl and trioctyl phosphine and the latter to the phosphine oxide which is a metal complexing agent; it was used for extracting uranium. I believe we also made the triscyanoethyl derivative from acrylonitrile and other derivatives ... The glyoxal process was discovered by Laporte, but Long obtained a license and we developed it from their initial lab process to commercial manufacture. I worked directly for Bob Long for many years and was involved in technology licensing, so I got involved, for example, with the phosphine products as a coordinator between Bound Brook and Welland. I always believed that Long should have been honored by the Commercial Development Association ... for leading the way on ... such important developments." Jay Leavitt to author, email, January 2, 2002. In 1972, American Cyanamid advertisements announced that the corporation "now has a pilot plant designed exclusively to produce phosphine and its derivatives. A number of alkyl and substituted alkyl derivatives as well as related compounds such as phosphine oxides and dithiophosphinic acids, are already available. Contact Dr. Roy R. Miron, Manager, New Ventures Department, Bound Brook."

15. Aerotex products included: Lanaset resin, applied to woven and knitted wool fabrics; Sheerset resin, based on melamine, as a lasting crisp finish for cotton and rayon sheer fabrics; Lacet resin, as a stiffener for cotton and rayon Nottingham lace curtains; Aerotex softener H, a synthetic softener for wool, cotton, and synthetic fibers; Superset resin, applied to woven rayon and acetate fibers; Permel resin, a water repellent for synthetics, cotton, and wool; and Pyroset resin. American Cyanamid also developed a series of polyester Laminac laminating resins. In 1969, Cyanamid acquired I.R.C. Fibers Co. of Painesville, Ohio, formerly Industrial Rayon Corporation, founded in 1925. This assisted the marketing of Laminac resins. Polyester yarns and fabrics for the tire and industrial markets were expanded. Rayon manufacture was discontinued in 1972. In addition to plastic resins, Cyanamid produced Ionac ion-exchange resins, capable of both anion and cation exchange.
16. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50,* text on reverse of back cover.
17. In 1967, Richard L. Phelps, manager of manufacturing for the OCD, was sworn in as a member of Somerset County Park Commission. Phelps was also chairman of the Somerset County Traffic Safety Committee. L. E. Chittenden, manager of Public Relations, joined the newly organized six-member Somerset County Air Pollution Control Association (established by the New Jersey Air Pollution Control Commission at the request of the Somerset County Board of Freeholders). Bridgewater Township Planning Board honored retiring member John H. McMurray in a special resolution of "highest commendation." McMurray served the board 33 years, 26 as its chairman. He had helped organize Somerset County Planning Board, and was its chairman until 1964. William O. Allen and Michael A. Lisi announced their candidacies for "councilman-at-large" in the May 9, 1967 election in Franklin Township (south of the Bound Brook facility). Both were members of the Democratic party. Allen had been a councilman since 1961, and was mayor during 1964–66. Lisi was a former mayor. *Bound Brook Diamond 22* (March 17, 1967).
18. "Formica is Acquired by Cyanamid," *Bound Brook Chronicle,* April 26, 1956.
19. Charles E. Funk Jr., "The Information Center of American Cyanamid's Stamford Laboratories," *Journal of Chemical Education* 34 (1957): 507–9.
20. Margaret Rossiter, "Chemical Librarianship: 'A Kind of Womens Work' in America," *Ambix* 43 (1996): 46–58.
21. "A Preview," *Research Division News,* March 1958, 15-18.
22. Bill Hardy provides additional background on Joan Gallagher, who joined Bound Brook in 1953. "After working for a few years in the laboratory she took an M.S. in information management and became Librarian in 1963 when Miss Cole retired … When the Bound Brook library closed in December 1982, she took a position as Manager of Regulatory Affairs for the Chemical Division in Wayne. She retired in 1992." William Hardy to author, email, May 20, 2002.
23. "Literature and the Creative Process–Help or Hindrance?" *Journal of Chemical Documentation* 9 (1969): 183–89. See panel discussion opened by Klingsberg: "Printed and Other Impediments to Creation," 183.
24. In the 1963 supplement to the *Colour Index,* three members of the U.S. editorial

committee were shown as from Bound Brook: W. R. Howes, 1959–62; L. J. Manara, 1962–63; and J. P. Matteis, 1958. In the 3rd edition of 1971, however, there was only one member from Bound Brook, N. A. Inkpen.

25. Typical review articles by American Cyanamid Stamford chemists include Robert C. Gore, "Infrared Spectroscopy," *Analytical Chemistry* 30 (1958): 570–79, and Robert C. Hirt, "Ultraviolet Spectrophotometry," idem., 589–93.
26. Technical bulletins included Franklin C. Dexter, *Practical Spectroscopy* (Technical Bulletin no. 841) (Bound Brook: American Cyanamid Company, Dyestuff Department, 1957).
27. "A Good Color for Growth: Calco Oil Red ZMQ," *Plastics Dyelines*, June 1963, 1, 4.
28. F. O. Sundstrom and E. I. Stearns, *Dyeing Paper White* (Technical Bulletin no. 830, revised) (Bound Brook: American Cyanamid Company, Dyes Department, 1957).
29. Among the Jerry Allison paintings undertaken for American Cyanamid and held today at Chemical Heritage Foundation, Philadelphia, is one of William Henry Perkin examining a sample of silk dyed with aniline purple (mauve), and another of Friedrich August Kekulé explaining his benzene ring theory to assistants. A leading designer and supplier of shade cards to American Cyanamid in the 1960s was Economy Color Card Co., of Brooklyn.
30. By 1960, American Cyanamid products were sold in eighty countries. In that year new overseas ventures were established: Cyanamid de Venezuala C.A.; Cyanamid Taiwan Corporation, with Taiwan Sugar Corporation, to manufacture pharmaceuticals; a Lederle pharmaceutical production unit in Pakistan; and an antibiotic fermentation facility in India.
31. F. F. Loffelman, "Calcobond Dyes: A New Fiber-Reactive Dye System," *Research Quarterly*, Spring 1968, 1–4.
32. Jay Leavitt to author, email, June 11, 2003.
33. A flow chart for the Catan process is shown in R. Norris Shreve, *Chemical Process Industries* (International Students Edition) (New York: McGraw-Hill, 1967), 3rd ed., 814.
34. O. C. Karkalits, C. M. Vanderwaart, and F. H. Megson, U.S. patent no. 2,891,094, June 16, 1959.
35. A. G. Potter, "Technical Conference: Catalytic Aniline," *Research Division News*, December 1958, 3. This was a contribution to the Skytop technical meeting held on October 21, 1958. During World War II American Cyanamid had collaborated in development of the fluid cracking catalysts used in the production of high-octane aviation gasoline and butadiene.
36. Vanderwaart, 30.
37. Ibid., 31.
38. Gerard A. Forlenza to author, email, April 25, 2002.
39. "In time Raymond was succeeded by Bob Maddox who flew his own two-engine plane to outlying plants. And he in turn was replaced [in 1966] by Jerry Forlenza." Unpublished typescript reminiscences of C(ornelius) Marsden Vanderwaart, 31–2 (hereafter Vanderwaart). Forlenza was appointed assistant general manager at the ECD in 1958, and returned there in 1966 as president after serving as assistant to Turchan at the OCD.

40. *Bound Brook Diamond* 22 (February 21, 1957): 1–2. In 1958, McAuliffe was replaced as ECD general manager by T. P. Forbath. Vanderwaart and his colleague Shen Wan were each in charge of a group of engineers.
41. Vanderwaart, 32. The conclusion is contradicted by Isaiah Von: "I think Vanderwaart overstated his part in the failure. When he got involved the die was long cast. I would say he had zero responsibility." Von to author, email, June 11, 2001. Vanderwaart moved on to a post at Wayne, with the Industrial Chemicals Division, and then to the resins plant at Wallingford. He returned to Bound Brook in 1970, where he worked on various projects, including a continuous beta-naphthol process for Willow Island (see chapter 7). Useful perspectives on the difficulties confronted in scale-up in the late 1950s appear in Richard Fleming, ed., *Scale-Up in Practice* ("A Collection of Papers Originally Presented in Philadelphia, Pa., in April 1958, under the Auspices of the Philadelphia–Wilmington Section of the American Institute of Chemical Engineers and the School of Chemical Engineering, University of Pennsylvania") (New York: Reinhold, 1958). See in particular, Henry J. Orgozaly (Esso Research & Engineering Company, Linden, N.J.), "The Use of Pilot Plants in Scale-Up" (1–15); Fred W. Kopf (Atlantic Refining Co., Philadelphia, Pa.), "Pitfalls in Scale-Up" (69–85); and Robert L. Hershey (E.I. du Pont de Nemours & Co., Inc., Wilmington, Del.), "Organizing for Scale-Up" (117–34).
42. In 1963, the title technical associate was established to acknowledge exceptional technical contributions, and provide professional advancement paralleling managerial growth opportunities.
43. The Gordon Research Conferences were inaugurated in 1931 as a summer school at Johns Hopkins University. In the 1930s this initiative became the American Association for the Advancement of Science–Gibson Island Chemical Research Conference, renamed in 1947 in honor of the principal organizer, Neil Elbridge Gordon, professor of chemistry, Johns Hopkins University. See Andrew Mangravite, "A Fellowship Foretold: Origins of the Gordon Research Conference?" *Chemical Heritage* 20, no. 4 (Winter 2002/3): 21.
44. "Advanced Education Opportunities Now Open to Research Division Personnel. Cyanamid Developing Policy to Provide Support for Qualified Applicants," *Research Division News*, March 1958, 1–3.
45. Reviewers from Bound Brook included C. Maresh, G. E. Coven, and R. L. Cox (for *Analytical Chemistry*).
46. David A. Hounshell and John Kenly Smith Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980* (Cambridge: Cambridge University Press, 1988), chapters 16, 17, 22, 25.
47. N. H. Furman, "Impressions of a Consultant," *Research Division News*, March 1958, 4–6. Furman's account had originally appeared in the Bound Brook publication *Analytical News*.
48. William Seaman, "Review of Program for Research Fellows and Research Associates," *Research Division News*, December 1958, 31–2, on 31.
49. "Recent Research Realignments Reviewed," idem., 17–18. The other members of the Research Coordination Committee were Robert C. Swain (ex-officio), previously engaged in the management of the Research Division at Stamford (subsequently

corporate vice president of research), F. E. Fontaine, T. H. Jukes, J. H. Paden, A. L. Peiker, R. O. Roblin, G. L. Royer, and M. Scalera. Bourland was appointed president of the Agricultural Division in 1965, and a vice president of American Cyanamid in 1967.

50. The MIT School of Chemical Engineering Practice was opened in 1916 following the suggestion of Arthur D. Little. His former partner, William H. Walker, had taught at MIT since 1904, and emphasized the benefits of industrial-academic ties. The school was originally funded by George Eastman, and later by Eastman and DuPont. John Mattill, *The Flagship: The M.I.T. School of Chemical Engineering Practice 1916–1991* (Cambridge, Mass.: David H. Koch School of Chemical Engineering Practice, MIT, 1991). American Cyanamid set an important precedent by providing funds for some of the students at Bound Brook. "The M.I.T. Practice School at Bound Brook," *Research Quarterly*, Summer 1969, 1–2.
51. The new approach involved the applications of thermodynamics, chemical kinetics, reactor design, transport phenomena, and a host of general mathematical and theoretical interrelationships, and process principles, to design, construction, commission, control, and management of manufacturing plant. It involved the fluid and solid dynamics of materials handled in bulk, and heat and mass transfer between and within phases. For the development of chemical engineering, see Nathan Rosenberg, "Technological Change in Chemicals: The Role of University-Industry Relations," in *Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry*, ed. Ashish Arora, Ralph Landau, and Nathan Rosenberg (New York: Wiley, 1998), 193–230, esp. 199–208.
52. Mattill, *The Flagship*, 36–7, 39–44, 48–56. Illustrations of the Bound Brook Practice School appear on 40–1. See also "Chemical Plant Campus Teaches Students Industry Slant," *Chemical Week*, March 7, 1959. Other stations operating during this period were Bayway (Esso Standard Oil Co.), 1958–65, Manhattan (Halcon International, Inc.), 1965–66, and Oak Ridge (Oak Ridge National Laboratory), 1966–82. The latter placed restrictions on the number of non-United States citizens, which meant that there were times when the proportion of foreign students at Bound Brook was more than the practice school and American Cyanamid liked. The Bayway station, at Linden, New Jersey, provided access to several continuous petrochemical processses, but was less successful than Bound Brook, and closed in 1965.
53. Mattill, *The Flagship*, 55.
54. Ward Worthy, "Herbert Brown Wins 1980 Priestley Medal," *Chemical and Engineering News* 58 (July 7, 1980): 21–23, quoting Brown on 22.
55. In 1959, Bound Brook chemists investigated the new one-step acrylonitrile process based on reacting propylene, ammonia, and air (oxygen) over a fluidized bed catalyst, as developed by Standard Oil Company (Ohio), or Sohio. This process, introduced in 1959–60, reduced the cost of acrylonitrile considerably.
56. Among those engaged in research into dyes for acrylics during 1957–58 were A. P. Paul and Warren S. Forster. In keeping with research reporting procedures, Paul submitted a monthly letter, copied to Technical Files, while Forster drew up periodic progress reports. Certain of these internal research reports are held at Bound Brook

Memorial Library. See also C. E. Lewis, "Dyes for Acrylic Fibers," *Research Division News,* December 1958, 5. This was based on one of the Bound Brook Skytop presentations, given on October 21, 1958.

57. "American Cyanamid," *Modern Textiles* 56 (August 1975): 72.
58. Jay Leavitt to author, email, April 21, 2002.
59. Erik Verg, Gottfried Plumpe, and Heinz Schultheis, *Milestones: The Bayer Story, 1863–1988* (Leverkusen: Bayer AG, 1988), 284–89.
60. "Urethane Plastics–Polymers of Tomorrow," *Industrial and Engineering Chemistry* 48 (1956): 1383–91. The Society of Plastics Industry gave the name urethane foam to what was previously called isocyanate, polyurethane, or polyester foam. The main isocyanates are TDI (a blend of 2,4- and 2,6-toluene diisocyanate), used in the manufacture of flexible foams (upholstery, bedding, seat cushions, etc.), paints, surface coatings, elastomers, and adhesives, and MDI (methylenediphenyl diisocyanate, or diisocyanato diphenyl methane), used for rigid foams (insulation, structural components), elastomers, and adhesives.
61. William Baptist Hardy and Robert Putnam Bennett, "Process for producing urethanes," U.S. patent no. 3,467,694, September 16, 1969; filed October 15, 1965. During 1953–59, Hardy was, as section manager, Chemicals and Intermediates Research, in charge of research into rubber and plastics additives, chemical intermediates, explosives, and new processes. This was an important period for the development of American Cyanamid's extensive line of long-lived plastics additives. See William B. Hardy, "Commercial Aspects of Polymer Photostabilization," in *Developments in Polymer Photochemistry-3,* ed. Norman S. Allen (Barking, Essex, England: Allied Science Publishers, 1982), 287–346.
62. Jay Leavitt to author, email, April 21, 2002.
63. "Elastomer Marketing Specialist," *ChemLines* 22 (October 1973): 2.
64. During 1948–50, Loper worked on packaging films at Reynolds Metals, Plastics Division, Gary, Indiana.
65. Robert Long headed the Commercial Development Department. In 1965, J. L. Naylor was assistant to the general manager; the OCD controller was Charles R. Oram; and legal counsel Nicholas E. Curtiss. There were four product and two commercial departments: Dyes and Textile Chemicals, headed by W. M. Boyce; Rubber Chemicals, which included Cyanacryl acrylic elastomers, Cyanaprene urethane elastomers, and Numa spandex fiber, run by R. Hydeman; Intermediates, headed by T. E. Hazell; Refinery Chemicals, headed by R. G. Keppler; Sales and Service; and Advertising and Promotion. At Bound Brook, T. F. Cooke Jr., was assistant director, R&D, H. J. Rodenberger business manager, and the following were in charge of technical work: Dr. J. J. Leavitt, Exploratory Research; G. L. Wiesner, Process Development; Dr. J. T. Woods, Analytical R&D; Truman Koehler, Systems Analysis; Dr. W. B. Hardy, Research Services; Dr. H. R. McCleary, Dyes R&D; Dr. John F. Hosler, Intermediates R&D; Dr. Guido Mino, Rubber Chemicals R&D; and R. G. Weyker, Textile Chemicals. R. H. Ebel was head of Refinery Chemicals R&D, based at Stamford. Hossler received his B.S., M.S., and Ph.D., in chemistry, at Penn State College. He joined Bound Brook as a research chemist in the Intermediates and Chemicals Group in 1951. In 1955 he was promoted to group

leader, Special Chemicals Group, and two years later became manager of pigments research. Subsequently he managed Intermediates R&D, and in 1968 was transferred to the Formica Corporation, as assistant to Jason Salsbury, vice president, R&D.

66. Gerard A. Forlenza to author, email, May 4, 2002.
67. Forlenza to author, email, April 25, 2002.
68. Ibid.
69. Ibid., April 23, 2002.
70. The plant manager's principal staff in 1964 were the production managers of manufacturing departments: Dyes, Anthony J. Paradiso (Paradiso joined Bound Brook in 1963, during 1968–72 was national sales manager, dyes and textile chemicals, in 1972 became assistant plant manager, in 1974 plant manager, and in 1976 moved to Princeton); Intermediates, W. T. Ries; Rubber Chemicals, L. F. Van Eck; Organic Pigments, R. J. Clay; and Pharmaceuticals, R. H. Wharton. The departments were supported by the Service Groups: Technical Operations, William Allen; Plant Services, W. A. Weber; Medical, Dr. E. M. Hartmann (medical director); Shift Operations, J. M. Donaruma; Material Services, J. M. Waller; Industrial Engineering, L. E. Beiswanger; Loss Prevention, T. A. Ventrone; Personnel Operations, G. J. Brucia; and Public Relations, L. E. Chittenden. Ventrone's responsibilities included the Fire Brigade, while Weber oversaw Maintenance & Construction, Central Engineering and Utilities. George Hedden's staff included: J. H. Spinnenweber, plant accountant; E. A. Lawrence Jr., staff assistant; and M. J. Duffy, supervisor of labor relations. The labor relations office negotiated working contracts with hourly employees who were members of Local 111, International Chemical Workers Union.
71. "Later when I became president of my own divisions I instituted an independent long-range research effort reporting directly to the president's office. I played a very active role together with the divisional research director in selecting areas for this long-range research. The funding for the long-range research was allocated to the operating departments. I must say that I did get some occasional flash back from the department heads complaining that they were being assessed without having any say in or control of the long-range research. Actually they did have some say; this was by influencing me on the merits of interesting areas of research, but it is true they did not have control of this research effort or of the magnitude of such effort. The magnitude of the long-range research varied depending on the subjects being investigated. However, it did amount to 10 to 20 percent of the total divisional research budget." Forlenza to author, email, May 6, 2002.
72. Jay Leavitt to author, email, May 21, 2002.
73. "American Cyanamid's New Organic Chemicals Division Research Laboratory," *Analytical Chemistry* 39 (June 1967): 84A–86A.
74. *Research Quarterly*, Spring 1968, 7.

CHAPTER SEVEN

1. See announcement in *Chemical and Engineering News* 37 (March 16, 1959): 74. For

Scalera see *American Men and Women of Science*, 13th ed., s.v. "Scalera, Mario." In 1967, he was a regents professor at the University of California at Riverside.

2. Erwin Klingsberg, "American Cyanamid and its European Research Institute: A Ten-Year Boondoggle," paper presented to the Division of the History of Chemistry, American Chemical Society, 217th national meeting, Anaheim, March 21–25, 1999. Klingsberg to author, interviews, 2001 and 2002.
3. William B. Hardy to author, telephone, May 1, 2002.
4. Isaiah Von to author, email, August 26, 2001.
5. Glendale's products found application in protective plastic shields, and similar devices, including in military applications during the 1991 Gulf War (Operation Desert Storm). "Two types of laser absorption devices manufactured by Cyanamid's Glendale Protective Technologies, Inc. were used to protect American pilots from visible and non-visible lasers as they flew nighttime sorties ... Based upon military specifications, Glendale, Cyanamid's Stamford Research Center and the technical services group in Bridgewater, NJ [Bound Brook] developed visors and spectacles for use by the Navy, Air Force and Army." From "Glendale Lasers Aid Troops," [*Cyanamid*] *Focus*, April–May 1991. See also "Allan Ellis Sherr," typescript biography, Bound Brook Memorial Library. Sherr had worked on chemicals for making plastics fire resistant and infrared absorbing products at Stamford. He eventually became the technical director of Glendale. In 1969, W. H. Forster at Bound Brook investigated the use of Calco dyes as laser absorbers as part of a government sponsored program.
6. "Cyanamid Expansion Plans Use Successes of R&D Scientists at Bound Brook Laboratories," *Bound Brook Diamond* 33, no. 14 (September 23, 1968): 1.
7. Cyalume products are based on the reaction of phenyl oxalate ester, bis(2,4,5-trichlorophenyl-6-carbopentoxyphenyl)oxalate, with hydrogen peroxide. The ester is oxidized, affording an intermediate whose decomposition is catalyzed by a dye. As a result the dye is electronically excited, and visible light is emitted, the color of which is determined by the nature of the dye. This is chemiluminescence. In 1991, Cyalume chemical lightsticks also saw service in the Gulf War, in which over a million non-visible infrared lightstick were used. "Chemical Light Plays Role in War," *Focus,* April–May 1991. Production of lightsticks was subsequently licensed to Omniglow Corporation.
8. Maurice Tordoff, *The Servant of Colour: A History of the Society of Dyers and Colourists, 1884–1984* (Bradford: Society of Dyers and Colourists, 1984), 325–27, 348–9. Stearns was for many years chairman of the AATCC Executive Committee on Research. He retired from American Cyanamid in 1972, to take up an appointment as professor of textiles at Clemson University, a post he held until 1977. During his career, he authored over 100 technical papers, and his name appeared on 20 patents. His hobby was ornithology. He was a founder and past president of Urner Ornithological Club. His name was chosen by the New Jersey Audubon Society for the award given each year for the out-of-state team of ornithologists that observed the largest number of species in one day. For two decades he held the unofficial record for the number of species of birds seen during one day in New Jersey. As a Presbytarian he served as an elder at churches in

Illinois, and Westfield, New Jersey. See obituary notice, *Textile Chemist and Colorist* 24, no. 3 (March 1992): 32, and biographical note, Bound Brook Memorial Library.

9. After 1945–54, when new derivatives had provided routes to direct, sulfur, and vat dyes, research was aimed at novel approaches to fast dyeing of cellulose to take into account new finishes, dyeing of nylon and other synthetic fibers, and theoretical work on the relationship between color, structure and fastness, affinity of dyes for fibers, and kinetics of absorption. See also Vivien Walsh, J. F. Townsend, Basil G. Achilladelis, and C. Freeman, *Trends and Innovations in the Chemical Industry* (University of Sussex: Science Policy Research Unit, 1979).
10. "The Flood of 1971," *Bound Brook Diamond, Special Supplement* 37, no. 13 (October 1971): 1, 2.
11. "Massive Cleanup Puts Bound Brook Plant Back in Business after Destructive Flood," *Cyanamid News* 15, no. 9 (September 1971): 1–3; and "Plant Recovers from Costly Flood," *Bound Brook Diamond* 37, no. 13 (October 13, 1971): 1–2.
12. Isaiah Von to author, email, August 26, 2001.
13. Jay Leavitt to author, email, April 23, 2002.
14. The following reported to Mino: Hardy, Intermediates R&D; Sam Kaizerman, manager, Rubber Chemicals R&D; H. R. McCleary, manager, Dyes and Textiles R&D; and Rauhut. Robert Saxon, as group leader, Elastomers Group, Rubber Chemicals R&D, at Bound Brook, reported to Kaizerman. Ebel, manager of Refinery Chemicals Research, reported to Paden.
15. "Program, Cyanamid Technical Conference, Wednesday, October 25, 1972, Far Hills Inn, Somerville, New Jersey."
16. In 1977, Loper became president of the Industrial Chemicals Division, and in 1978 was appointed president of Cyanamid International, a post he held until retirement in September 1982. Ben H. Loper to author, email, May 12, 2002.
17. Clifford D. Siverd, obituary, *New York Times*, February 3, 1998. Siverd, who had joined Calco in 1943 through the United Color & Pigment acquisition, in 1960 became head of the Agricultural Division. In 1965 he was appointed vice president, American Cyanamid, responsible for the Agricultural and Consumer Divisions, in 1966 director, and in 1967 member of the Executive Committee. During 1970–71, he was chairman of the Manufacturing Chemists' Association.
18. "The Bound Brook Plant and Effluent Treatment Facilities. February 1975. American Cyanamid Company. Bound Brook Plant." Prospectus with introduction by Ben H. Loper, president, Organic Chemicals Division, to the Executive Committee, February 21, 1975, and attachments, numbered consecutively (hereafter Loper). Quoting from Loper's introduction, 2. The main body of this prospectus consists of sections dealing with effluent treatment facilities, financial data, endorsements, plant viability, and a plant rehabilitation program.
19. Attachment to Loper, 3. Von points out that PP&E figures for the 1970s should be treated with caution, since the decade was characterized by unusually high levels of inflation. The primary product lines listed were: vat, azo, solvent, and acrylic dyes; chemical intermediates, including dimethylaniline, diethylaniline, monoethylaniline, diphenylamine, sulfanilic acid, *ortho*-benzoylbenzoic acid, and the important

intermediate Tobias acid, for sale and for use in other manufacturing units; rubber chemicals including antioxidants; Cyanaprene urethane elastomers; Cyanacryl acrylic elastomers for tires; thiazole accelerators, MBTS (2,2′-dithiobisbenzothiazole, or mercaptobenzothiazyldisulfide), and NOBS (2-(morpholinothio)benzothiazole); organic pigments, including azo reds, phthalocyanine pigments; sulfa drugs; and pharmaceutical, agricultural, and animal health products, including sulfamethazine for Aureo S-P 250 and Aureo S-700 feed supplements, loxapine, Hetrazan diethylcarbamazine, Diamox acetazolamide, Myambutol, ethambutol hydrochloride, DSS/DCS surfactants, levamisole, Warbex famphur, Robenz robenidine hydrochloride, Pigdex injectable iron (an iron supplement for pigs), Avenge wild oat herbicide (1,2-dimethyl-3,5-diphenyl-1H-pyrazolium methyl sulfate); Pathilon tridihexethyl chloride; and Artane (trihexyphenidyl, an antidyskinetic drug). "Approximately $34 million in capital has been invested in new facilities and expansions at Bound Brook since 1971, including the West Utilities expansion, boiler conversion project, purchased power facilities, automated product warehouse, the PNTS [5-nitro-*para*-toluenesulfonic acid]/DNS [4,4′-dinitro-2,2′-stilbenesulfonic acid] facility, the sulfanilic acid facility, methylene blue expansion, MBT autoclave, sodium MBT expansion, NOBS/MBTS plant, SO_2 abatement system, cyan blue expansion, the azo pigment facility, pharmaceutical building 102 job shop, and facilities for robenidine, wild oat herbicide, and ASC [acetylsulfanilyl chloride]/ACET." Attachment to Loper, 4.

20. Ibid.
21. Ibid., 5.
22. Ibid., 33
23. Ibid., 6. Demolition planned during 1975 included: building 49, sulfuric acid, built 1941; building 56.2, drum concentrator and tankage, 1941; building 55, nitric acid processing, 1918 (part retained as alkylating facilities for thiazole intermediates for antioxidants); building 54, mixed acid, 1918, which "has no forseeable requirements after BN shutdown in 1975" (37).
24. Unpublished typescript reminiscences of C(ornelius) Marsden Vanderwaart, 34.
25. "Cyanamid Makes News of Importance to You!" Promotional leaflet, undated, and "Cyanamid Organic Chemicals Division. Bound Brook, New Jersey," Color, Textile and Intermediate Chemicals Department report, 1976.
26. "Nowadays ... the difference [in use of pigments] is much greater. In the past 20 years since I retired, the use of color has greatly increased in newspapers, so that today there are hardly any papers that don't have color. In addition most newspapers carry large quantities of color advertising inserts ... there is a big increase in packaging which is usually quite colorful. I would guess that the printing ink business is 2–3 times [or more] what it was 20 years ago." Von to author, email, July 12, 2001.
27. Prowl is *N*-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine. In 1973, it was made on a pilot-plant scale at Bound Brook.
28. "Dyestuffs: A Future," *TRC News*, September 1977, 4. The Sandoz connection with Toms River ended in the early 1980s.
29. Robert K. Fourness, "The Contribution of Research and Development–Past Contribution," *Journal of the Society of Dyers and Colourists* 94, no. 4 (April 1978):

125–31. "The last two or three decades have seen another change in the direction of most R&D in the dye industry. Much of it has been directed towards modifying existing types in order to provide dyes suitable for the now-common man-made fibres as well as enabling these dyes to meet the new standards of fastness required by changing life styles and a more discriminating consumer … Even before this time the chemistry of some vat dyes, for example, was getting nearer to the point where the result achieved was barely worth the effort and cost. One of the undoubted benefits brought by the reactive dyes … has been described as 'giving an opportunity for escaping from the highly competitive vat dye field … Just as the appearance of acetate rayon, a quarter of a century or so earlier, had demanded R&D to find suitable dyes, so did the various man-made fibres which appeared after the war. These fibres, particularly polyester, require disperse dyes of greater complexity than had been available hitherto, and R&D by the dyemakers has made them available. The old and well-tried principle of the basic dye has been, through R&D, extended by incorporating basic groups into azo and anthraqinonoid type dye structures and in this way, has provided suitable dyes for acrylic fibres" (126–7).

30. The United States was the second largest producer of dyes in 1980, after West Germany. Third was the United Kingdom, fourth Japan, and fifth Switzerland. Dyes were made in twenty-six countries, of which only these five were major producers.
31. Frank McNeirney, "The Japanese Dye Industry," *American Dyestuff Reporter* 71 (May 1982): 15–23, 33–4, 41, 44.
32. After serving as a development chemist, commencing 1946, Bann was promoted to chief chemist, prior to taking up management posts, first at Bound Brook, and from 1976 at the Marietta facility. See *American Men and Women of Science,* 19th ed., s.v. "Bann, Robert Francis."
33. Dunn and Konzelmann, to William Allen, November 18, 1976. This gives 1976 production of finished products in the Dyes and Intermediates units. SME/AmCy.
34. Isaiah Von to author, email, July 12, 2001. Von adds that there was a restricted use of vats as pigments for printing ink, paint and plastic use, since "special efforts would be needed during the final step to make sure the vat crystal met the uniformity of the pigment color and strength standard."
35. Gerard A. Forlenza to author, telephone, April 23, 2002. In 1977, Loper and Forlenza switched jobs, Loper becoming president of the Industrial Chemicals Division.
36. Ibid. American Cyanamid purchased DuPont's vat dye technology, with the exception of Ponsol yellow, around 1979. Chemists at Bound Brook attempted, without success, to establish the constitution of Ponsol yellow, the technology of which was later sold to CIBA-Geigy. After Isaiah Von retired in June 1981 he acted as consultant, mainly to Asian firms, until 1994. Von to author, personal interview, November 28, 2003.
37. "Cyanamid Explosion Kills One," *Chemical and Engineering News* 59 (June 15, 1981): 7.
38. "What's Up," S+44, January 6, 1979. This was issue no. 44 of the mimeographed

newsletter, the S referring to the strike. From December 5, 1978, it had appeared daily. Bound Brook Memorial Library.

39. *American Men and Women of Science,* 19th ed., s.v. "Berry, William Lee."
40. Building 43 contained 18 coupling tubs, ranging in size from 23,000 to 110,000 PV (production volumes). In general, each coupling tub had associated with it two smaller tubs located on the third floor. These tubs, of which there were twenty-two, ranged in capacity from 4,000 to 16,000 PV. Most were Haveg lined. Half were abandoned. One continuous diazotization apparatus was in use, mounted on castors for ease of transfer to available coupling tubs.
41. Thus a widely publicized New Jersey Supreme Court ruling in 1984 found four companies that had successively operated a mercury-processing plant between 1929 and 1974 liable for cleanup and remediation costs of a creek where mercury-containing waste was dumped. This ruling, carried unanimously by the five justices, was notable because it was based on retroactive application of the 1977 Spill Act. Silvio Barabas, "Indiscriminate Waste Discharges are Self-Incriminating," *Water Quality Bulletin* 9 (1984): 2.
42. Robert J. Tucker and Peter V. Susi, "Stabilization of Polypropylene Multifilaments: Utility of Oligomeric Hindered Amine Light Stabilizers," *Polymer Stabilization and Degradation,* ed. Peter P. Klemchuk (ACS Symposium Series no. 280) (Washington, D.C.: American Chemical Society, 1985), 137–47. Susi and Tucker had previously worked at Intermediates R&D, Susi on synthesis, and Tucker on product development.
43. *American Men and Women of Science,* 19th ed., s.v. "Bernady, Karel Francis."
44. A decade earlier, in 1978, BASF Wyandotte Corporation purchased the GAF dye-making facility at Rensselaer.
45. *Cyanamid at 85* (Wayne, N.J.: American Cyanamid, Public Affairs Division, 1992), 6, special section of *Focus* 13, no. 3 (1992).
46. Marc S. Reisch, "Cytec Breaks Free of American Cyanamid," *Chemical and Engineering News* 72 (April 25, 1994): 29–33, on 30. A connection with the past was renewed when Cytec purchased the amino resins business of British Industrial Plastics (BIP) in 1999. In 1993, ICI in England spun off its pharmaceutical, agrochemicals and specialty businesses, including dyestuffs, into a separate corporation, known as Zeneca (from 1999 the Anglo–Swedish AstraZeneca).
47. "AHP Signs Deal to Sell Cyanamid to BASF," internet announcement by Reuters, March 21, 2000, and *Chemistry and Industry,* April 3, 2000, 238. Other firms that moved out of, or reduced their involvement in, agrochemicals included CIBA-Geigy, Hoechst, Rohm and Haas, Rhône-Poulenc, Sandoz, Schering, and Shell.
48. "BASF Closes Agri-plant," *Chemistry and Industry,* May 21, 2001, 296.

CHAPTER EIGHT

1. Milton C. Whitaker was a vice president and director of American Cyanamid from 1930 to 1949, after which he served the corporation as a consultant. He was a former editor of *Industrial and Engineering Chemistry.*

2. Robert George Haldeman (Stamford), "Free Research Time," *Research Division News,* December 1958, 33–38. Paper delivered at American Cyanamid technical conference, Skytop, October 5–7, 1958.
3. David A. Hounshell and John Kenly Smith Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980* (Cambridge: Cambridge University Press, 1988), 573–90 (hereafter Hounshell and Smith). For a review of the development of industrial research at major U.S. corporations, particularly General Electric, DuPont, and AT&T, see W. Bernard Carlson, "Innovation and the Modern Corporation: From Heroic Invention to Industrial Science," *Science in the Twentieth Century,* ed. John Krige and Dominique Pestre (Reading, U.K.: Harwood, 1997), 203–25.
4. In 1972, American Cyanamid ranked eleventh among the top fifty U.S. chemical firms in terms of chemical sales, according to *Chemical and Engineering News.* In 1970, R&D expenditure was $46 million; in 1971 estimated at $41million (2 percent of sales); and in 1972 estimated at $40 million (1.7 percent of sales). The reduction from 1970 to 1971 was 11 percent, compared with 3 percent at DuPont and Celanese, and one percent at Union Carbide (from 1957 Union Carbide & Carbon was known as Union Carbide Corporation). Of twenty companies surveyed, seven increased R&D expenditure in 1971 (Dow Chemical, W. R. Grace, Allied Chemical, Hercules, Ethyl Corp., Olin, and Air Products). Donald J. Soisson, "Squeeze on Chemical R&D Spending Intensifies," *Chemical and Engineering News* 50 (January 17, 1972): 7–9. Combined spending for R&D and capital investment at American Cyanamid dropped from $100 million in 1971 to $85 million in 1972. It was estimated that chemical industry capital investment, in terms of 1972 dollars, "had been on something of a plateau for eight consecutive years since it reached $2.86 billion in 1965." Michael Heylin, "Chemical Firms Tight with Investment Money," *Chemical and Engineering News* 50 (January 24, 1972): 6–8.
5. *Chemical and Engineering News* 44 (January 13, 1966): 14.
6. Anthony T. James (Unilever Research Laboratory, Bedford, U.K.), "The Relationship between Industrial and Academic Laboratories," *Biochemistry in Industry,* ed. G. A. Snow (London: Academic Press, 1966), 36–39. Jointly with A. J. P. Martin, James developed gas chromatography in 1951.
7. "Chemical Industry in 2000: A More Worldly Involvement," *Chemical and Engineering News* 51 (January 15, 1973), 96–100, on 97–8.
8. Peter J. T. Morris, *The American Synthetic Rubber Research Program* (Philadelphia: University of Pennsylvania Press, 1989), 142. See also 50–59. For a typically optimistic review of corporate chemical research during the late 1940s, see D. H. Killeffer, *The Genius of Industrial Research* (New York: Reinhold, 1948).
9. John Kenly Smith Jr., "The End of the Chemical Industry: Organizational Capabilities and Industry Evolution," *Business and Economic History* 23 (1994): 152–61, on 159.
10. Fred Aftalion, *A History of the International Chemical Industry,* translated by Otto Theodor Benfey (Philadelphia: University of Pennsylvania Press, 1991), 371. For a review of the last decade of the 20th century, in which the interests of shareholders and financial analysts held sway, see the second edition, *A History of the International Chemical Industry: From "Early Days" to 2000* (Philadelphia:

Chemical Heritage Foundation, 2001). See also *Measuring Up: Research and Development Counts for the Chemical Industry* (Washington, D.C.: Council for Chemical Research, 2001).

11. Fred Dorf, "Bound Brook Technical Operations. March 26, 1964. Subject: Ideas for Cyanamid Opportunities." SME/AmCy. This includes a list of "Cyanamid Venture Ideas Generated at Bound Brook Technical Luncheon Sessions in February–March 1964," sent to "Dr. R. S. Long for forwarding to the Commercial Development Division. The tough job is ahead–developing profiles and implementing any of the ideas that look good. Perhaps this list will trigger some further suggestions." The list of items was divided as follows: Items 1–59 covered Building–Construction–Highways; 60–78, Pharmaceuticals–Cosmetics–Health; 79–95, Agricultural-Animal; 96–120, Recreation; 121–27, "Manufacture toys based on Cyanamid know-how" (scientific kits, such as "Learn About Dyeing," "The World of Color," "Learn About Rubber"); 128–33, Air–Water, including "Biodegradable detergents. Develop bacteria to degrade non-biodegradables"; 134–44, Industrial, including "Deeper penetration into sulfur color market," "Manufacture dyes for acetate market"; 145–51, Equipment and Service; 152–70, Miscellaneous Polymer Applications; 171–87, Miscellaneous Acquisitions; 188–98, Miscellaneous Marketing; 199–213, Miscellaneous; 214–24, Food. Among these suggestions were plastic grass (item 97), and manufacture and sale of scientific instruments (item 146). A useful survey of innovation in the chemical industry during the 1960s and 1970s is Michael J. Baker, "Success and Failure in Industrial Innovation," in *The Chemical Industry*, ed. D. H. Sharp and T. F. West (London: The Society of Chemical Industry/Chichester: Ellis Horwood, 1982), 205–21. For new venture divisions at DuPont and Monsanto, see Ashish Arora and Alfonso Gambardella, "Evolution of Industry Structure in the Chemical Industry," in *Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry*, ed. Ashish Arora, Ralph Landau, and Nathan Rosenberg (New York: Wiley, 1998), 379–457, on 424–27.
12. Nicolas Rasmussen, "Biotechnology Before the 'Biotech Revolution': Life Scientists, Chemists and Product Development in 1930s–1940s America," *Chemical Sciences in the 20th Century: Bridging Boundaries*, ed. Carsten Reinhardt (Weinheim: Wiley-VCH, 2001), 201–27, on 204.
13. Later research at American Cyanamid's Agricultural Division led to the development by Marinus Los of imidazolinone herbicides Assert, Arsenal, and Pursuit, the first of which was introduced in 1985. Apart from a range of sulfonamides introduced in 1992, no further developments in herbicides were made in the 20th century. Herbicides account for about 50 percent of the crop-protection market.
14. "University of Rochester, Department of Chemistry, Annual Newsletter, July 1, 1988–June 30, 1989," 6–8. Robert Wizinger-Aust was professor of color chemistry and organic chemical technology at Bonn until 1938, when he was dismissed by the Nazis as a Catholic belonging to a branch close to the Pope. From 1938–47 he was at the University of Zurich, and from 1947–66 at the University of Basel, as professor of color chemistry.
15. Ibid. Erwin Klingsberg, ed., *Pyridine and Its Derivatives* Part 1 (New York: Interscience, 1960). The four parts constituted volume 14 of the series "The

Chemistry of Heterocyclic Compounds." According to the promotional literature, "Frederick Brody and Philip Ruby of the Bound Brook Laboratories of the American Cyanamid Company discuss the synthesis of pyridine derivatives of all types, from non-pyridinoid starting materials, with a degree of thoroughness and penetration that far surpasses anything ever before attempted in the literature."

16. Jay Leavitt to author, personal interview, February 28, 2001. Erwin Klingsberg, "Preparation of Dithiolium Compounds," in *Organosulfur Chemistry: Reviews of Current Research,* ed. Matthijs J. Jannsen (New York: Interscience, 1967), 171–78.
17. Erwin Klingsberg, "New process for pyrazoles and pyrazolium salts. Also relates to new cationic dyes useful for coloring acrylic fiber. More specifically, it relates to aryl pyrazolium dyestuffs," U.S. patent no. 3,158,620, November 1964.
18. For a brief but useful discussion of blue-sky, market-oriented, applied, and basic research, see Harold A. Wittcoff and Bryan G. Reuben, *Industrial Organic Chemicals* (New York: Wiley-Interscience, 1996), 31.
19. The situation at ICI in the 1930s, as described by historian William J. Reader, is of particular interest. "Pharmaceuticals, the chemistry and technology of which are closely related to those which produced [selective weedkillers] illustrate yet again the uneasy fit between ICI's organisation, technical advance, and commercial policy ... With the growth of the pharmaceuticals business, the question of separating it from the Dyestuffs Division became more and more insistent, but it was not one to which the Board of ICI addressed itself with alacrity." William J. Reader, *Imperial Chemical Industries. A History,* 2 vols. (London: Oxford University Press, 1970), vol. 2, *The First Quarter-Century 1926–1952*, 458–9. However, in 1930 the Alkali Group began to favor speculative research. For I.G. Farben, see Jeffrey Allan Johnson, "The Academic-Industrial Symbiosis in German Chemical Research, 1905–1939," in *The German Chemical Industry in the Twentieth Century,* ed. John E. Lesch (Dordrecht: Kluwer, 2000), 15–56.
20. Hounshell and Smith, 223–48.
21. Carsten Reinhardt, "Basic Research in Industry: Two Case Studies at I.G. Farbenindustrie AG in the 1920's and 1930's," in *Determinants in the Evolution of the European Chemical Industry, 1900–1939: New Technologies, Political Frameworks, Markets and Companies*, ed. Anthony S. Travis, Harm G. Schröter, Ernst Homburg, and Peter J. T. Morris (Dordrecht: Kluwer, 1998), 67–88, on 72.
22. Ibid., 86.
23. In 1937, also, research was transformed at Westinghouse Electric and Manufacturing Company when the corporation hired academic physicist Edward Condon to direct programs that were engaged in fundamental research. See Thomas S. Lassman, "Industrial Research Transformed: Edward Condon at the Westinghouse Electric and Manufacturing Company, 1935–1942, *Technology and Culture* 44 (2003): 306–39.
24. Scott G. Knowles and Stuart W. Leslie, "'Industrial Versailles': Eero Saarinen's Corporate Campuses for GM, IBM, and AT&T," *Isis* 92 (2001): 1–33; and David Hounshell, "The Evolution of Industrial Research in the United States," in *Engines of Industrial Research at the End of an Era,* ed. Richard S. Rosenbloom and William J. Spencer (Boston: Harvard Business School Press, 1996), 13–85.

25. "The story of American technology is ... the tale of the historical decline of one set of complex ideas and the rise of another. The postwar era can be divided into two broad periods characterized by different perspectives on how technology has fit into the American economy and ethos ... conventional wisdom that resulted from World War II was that only big business, and big government, could nurture modern technology and innovation ... At some point, probably in the 1960s, the merits of size, of hierarchy, began to fade ... Size and reach, financial power and organization, became detriments rather than necessary prerequisites to innovation." Robert Teitelman, *Profits of Science: The American Marriage of Business and Technology* (New York: Basic Books/HarperCollins, 1994), 203–4.
26. Herbert C. Brown, "Chemical Discovery," *Chemical and Engineering News* 52 (July 29, 1974): 34–36, on 35–6.
27. Ward Worthy, "Herbert Brown Wins 1980 Priestley Medal," *Chemical and Engineering News* 58 (July 7, 1980), 21–23, on 22.
28. Jay Leavitt was research chemist, 1944–54, then assigned to the Research Division, 1954–58. He later undertook various assignments for the Organic Chemicals Division, prior to becoming head of Exploratory Research. After 1969, Leavitt became involved in negotiating licensing arrangements with other firms. He left Bound Brook in 1978, and retired in 1985. In 1967, as a member of the American Chemical Society's eighteen-member Chemical Abstracts Service (CAS) Advisory Board, he was coopted to the newly formed nine-member Marketing Panel, that served as an adjunct to the board. Leavitt was involved in American Cyanamid's attempt to introduce fluorescent bar codes during 1969–71, a venture that proved premature. The laboratories and offices engaged in this exercise were located at Manville. Von points out that "Cyanamid's efforts on bar codes involved the use of dyes. This could obviously not compete with black and white bars that are used now. This was quite a challenging project involving a lot of electronic instrumentation." See also *American Men and Women of Science,* 19th ed., s.v. "Leavitt, Julian Jay."
29. Erwin Klingsberg to author, February 21, 2001; and Klingsberg, "American Cyanamid and Its European Research Institute: A Ten-Year Boondoggle," paper presented to the Division of the History of Chemistry, American Chemical Society, 217th national meeting, Anaheim, California, March 21–25, 1999.
30. *American Men and Women of Science,* 14th ed., s.v. "Mino, Guido." Mino died in November 2002.
31. Erwin Klingsberg, "Successful Resolution of an Age Discrimination Suit," *ACS Professional Relations Bulletin,* June 1986.
32. E. Klingsberg, "Doing Heterocyclic Chemistry with Vat Dyes," paper given at heterocycle conference, Vienna, 1981. This dealt with the use of long-chain alkyl substituents to characterize refractory heterocyclic vat dyes such as Vat Green 3 and Vat Blue 6.
33. Klingsberg chaired the symposium "Ten Years after *Klingsberg vs American Cyanamid*–Have We Learned Anything?" at the American Chemical Society's 208th national meeting, Washington, D.C., August 21–25, 1995. The symposium dealt with illegal age discrimination.

34. Richard Madison to author, telephone, February 21, 2002. Madison retired from Bound Brook in 1981.
35. William Hardy to author, email, April 23, 2002.
36. Haldeman, "Free Research Time."
37. Erwin Klingsberg, "Literature and the Creative Process–Help or Hindrance?" *Journal of Chemical Documentation* 9, no. 183 (1969): 183–89, on 186. Jay Leavitt opines that it was lack of creativity as well as fear that prevented full use of free-time research.
38. Salsbury received his B.S. from Richmond in 1940, and Ph.D. from the University of Virginia in 1946. He joined Bound Brook in 1946, and was promoted to group leader in 1954. From 1957 to 1961 he was manager of the technical department at Santa Rosa. He directed the Fibers Division at Stamford from 1961, was director of research from 1963, and technical director from 1966. He was vice president, R&D, at Formica International, 1967–72. *American Men and Women of Science,* 14th ed., s.v. "Salsbury, Jason Melvin."
39. American Cyanamid, annual report, 1984, 6.
40. Aftalion, *International Chemical Industry* (1991), 320.
41. Erwin Klingsberg to author, telephone, March 3, 2000.
42. Jay Leavitt to author, email, April 21, 2002.
43. E. Klingsberg to J. G. Affleck (CEO, American Cyanamid, Wayne), early November 1976, SME/EK.
44. E. Klingsberg to J. M. Salsbury (Wayne), March 29, 1978. Copied to J. G. Affleck, R. H. Becker, G. Berkelhammer, James E. Longfield, R. J. Magee, M. M. Rauhut, and G. L. Sutherland, SME/EK. Longfield was director of process engineering at Bound Brook in the 1970s.
45. Klingsberg to Salsbury, April 27, 1978. Copied to J. G. Affleck, R. H. Becker, G. Berkelhammer, J. E. Longfield, R. J. Magee, M. M. Rauhut, and G. L. Sutherland, SME/EK.
46. "I am planning to discuss the matter at length with Drs. Matsuda, Gallivan, Coville and Coscia on July 27 and draw a plan for increasing creativity in the Department. Your suggestions will be appreciated." G. Mino to J. M. Salsbury, July 20, 1978, SME/EK.
47. Klingsberg to Salsbury, August 3, 1978. "Subject: 'Free time' research." Copied to J. G. Affleck, R. H. Becker, G. Berkelhammer, J. E. Longfield, R. J. Magee, M. M. Rauhut, and G. L. Sutherland, SME/EK.
48. Klingsberg to author, personal interview, February 21, 2001.
49. J. M. Salsbury to members of the SRI course on management innovation, August 30, 1978. Copied to F. E. Detoro, G. A. Forlenza, and J. A. Weicksel.
50. "Research Productivity," William B. Hardy to G. Mino, August 12, 1980, SME/EK.
51. On creativity and innovation, Mino wrote: "All scientists interviewed agreed that creativity and innovation are at a very low level in CRD and so are motivation and productivity. Management has been aware of this for some years and has made feeble and unsuccessful attempts to remedy the situation. The main problem stems from management's lack of understanding of creative people and the treatment of these people within the division. To begin with, when it comes to creative minds we

were not all born equal. In any given laboratory (within or outside the Company) there are only very few creative people. The others may be highly intelligent, well-organized, endowed with analytical minds that can dissect complex problems with ease and find valuable solutions, they may be innovative in their approach to management, but they do not have the spark, the new idea that will change radically our product lines, our businesses, the future of the Company. These people are soon recognized by management, singled out, pampered, promoted and remunerated. They form the cadres of future management and are put on many tracks all converging towards the top. There is nothing wrong with this, we must have good people in management and an early identification and selection of candidates is necessary and commendable, but this is only half the story. What about the creative fellow who often does not have the attributes of a good manager and should profitably contribute as a top scientist in his field? What are we doing for him? Most of the time he is enticed by rewards into a career in technical management for which he is ill-suited. Otherwise he can pursue technical work … He has little status within the Company and as he grows older he is looked upon as somebody who did not quite succeed. There is little wonder that older scientists become discouraged, sparkless and often technically inadequate. The fact that some of our senior scientists have retained their scientific excellence is a source of constant wonder to me.
Many creative people are unconventional, they do not fit the mold, some are difficult to manage, others are downright troublesome. A truly inquiring mind is driven by the need to know, by a curiosity that must be satisfied and that cannot be stifled by tight schedules. A creative scientist in most industries already makes a compromise when he chooses to work in industry because he knows that his field of inquiry will be restricted to certain areas that are of interest to the corporation. He accepts this. However, within the areas of interest he must be given some freedom to experiment, to roam around, to satisfy his drive to inquire and to discover. Unless management is willing to recognize the handful of creative people in our laboratory and to give them freedom and rewards, we will not have more of the same." "Improved Utilization of Scientists in CRD," G. Mino to Office of the Director, October 9, 1980, 4–5. Copied to A. T. Guertin, G. W. Kennerly, W. F. Linke, R. S. Long, J. E. Longfield, SME/EK.

52. Ibid., 7.
53. Ibid., 9.
54. Ibid., 11.
55. Ibid., 12.
56. Ibid., 15.
57. W. B. Duncan, "Lessons from the Past, Challenge and Opportunity," in *The Chemical Industry,* ed. Sharp and West, 15–30, on 22.
58. Edward G. Jefferson, "Challenges for the U.S. Chemical Industry in the 1980s," idem., 76–88.
59. Jefferson's leading role in directing DuPont into the life sciences from 1978 is described in Hounshell and Smith, 587–91. For a more recent approach to the management of technology see William L. Miller and Langdon Morris, *4th*

Generation R&D: Managing Knowledge, Technology, and Innovation (New York: Wiley, 1999).

60. However, as Von points out, the downfall of Bound Brook was also connected with increasing foreign competition, the spread of suburbs from New York, the loss of labor to the New Jersey pharmaceutical industry, and pollution problems associated with the Raritan River. Von describes the American Cyanamid management during 1960–80 as "honorable but stupid." Von to author, personal interview, November 28, 2003.
61. J. M. Salsbury to members of the SRI course on management innovation, August 30, 1978.
62. James G. Affleck, chairman, and George J. Sella Jr., president and chief executive officer, for the Board of Directors, annual report, February 7, 1984, 6.
63. "American Cyanamid," entry in Thomas Derdak, ed., *International Directory of Company Histories* (Chicago: St. James Press, 1988), vol. 1, 300–2, on 302.
64. Changes in the chemical industry during the last decades of the 20th century are described in Peter H. Spitz, ed., *The Chemical Industry at the Millennium: Maturity, Restructuring, and Globalization* (Philadelphia: Chemical Heritage Foundation, 2003). For the revival of traditional laboratory work in drug discovery see Peter Landers, "Back to Basics. With Dry Pipelines, Big Drug Makers Stock Up in Japan. Shunning High-Tech Gizmos, The Asian Scientists Score with Traditional Lab Work. 'High Value on Weird People'," *The Wall Street Journal*, November 24, 2003.

CHAPTER NINE

1. Description of Calco Chemical Company in 1930, from unknown publication, 15. Copy held at Bound Brook Memorial Library.
2. D. H. Killeffer, "Industrial Poisoning by Aromatic Compounds," *Industrial and Engineering Chemistry* 17 (1926): 820–22, on 820.
3. Metha[e]moglobinaemia is generally spelt as methemoglobinemia.
4. Killeffer, "Industrial Poisoning by Aromatic Compounds." See also Christopher C. Sellers, *Hazards of the Job: From Industrial Disease to Environmental Health Science* (Chapel Hill: University of North Carolina Press, 1997), 23, 35–37.
5. Donald O. Hamblin and Arthur F. Mangelsdorff, "Methemoglobinemia and Its Measurement," *Journal of Industrial Hygiene and Toxicology* 20 (October 1938): 523–30.
6. Hulda Kloenne, interview with H. F. Gilbert, safety director, American Cyanamid Co., "Cleanliness Brings Good Repute to Chemical Plants," *Chemical Industries* 54 (1944): 512–14.
7. Donald O. Hamblin, medical director, American Cyanamid, New York, to Robert A. Kehoe, June 11, 1943, and attachments, including: Harrison S. Martland, M.D., Newark, chief medical officer, Essex County, to D. O. Hamblin, May 27, 1943; Report of Ellis J. Robinson, Stamford Laboratories, Chemotherapy Laboratory, June 2, 1943; Kettering Laboratories report on 2-aminothiazole, June 10, 1943;

D. O. Hamblin to R. Kehoe, June 24, 1943 (includes sharing of expenses with Monsanto for 2-aminothiazole toxicity studies); Francis F. Heyroth (Kettering) to D. O. Hamblin, August 17, 1943; Autopsy Report, Harrison S. Martland, M.D., September 3, 1943; Heyroth to Hamblin, December 13, 1943; Hamblin to Kehoe, April 25, 1943; Hamblin to Kehoe, December 14, 1944 (regarding the forthcoming trial over Bryant's death), SME/RS. Robert Kehoe's papers are held at the University of Cincinnati Medical Heritage Center Archives.

8. D. O. Hamblin to R. Kehoe, April 25, 1945, SME/RS.
9. William B. Deichmann to R. M. Watrous, plant physician, Abbott Laboratories, North Chicago, Illiniois, August 5, 1946, and F. F. Heyroth, Kettering Laboratories, to D. O. Hamblin, September 5, 1946. Hamblin to Heyroth, September 10, 1946, and Kehoe to Hamblin, September 17, 1946, SME/RS. Hamblin and J. M. Carlisle of Merck expressed differences with Watrous over the toxicity of 2-aminothiazole. See also R. M. Watrous, "Health Hazards of the Pharmaceutical Industry," *British Journal of Industrial Medicine* 4 (1947): 111–25.
10. Two papers dealt with sulfa drug intermediates: William B. Deichmann, K. V. Kitzmiller, F. F. Heyroth, and S. Witherup, "The Physiological Response of Experimental Animals Following Absorption of 2-Aminothiazole," *Journal of Industrial Hygiene and Toxicology* 30 (1948): 71–78; and Joseph F. Treon, Howard Wright, Karl V. Kitzmiller, and Waldo J. Younker, "The Physiological Response of Animals to 2-Aminodiazine and 2-Amino 4-Methyl Pyrimidine," idem, 79–91.
11. Sharon Bertsch McGrayne, *Prometheans in the Lab: Chemistry and the Making of the Modern World* (New York: McGraw-Hill, 2001), 168–97.
12. V. L. King and C. H. Nichols (chemical engineer), "Air Pollution at Calco," draft manuscript, dated January 2, 1943. The manuscript was updated during or after 1944.
13. Victor L. King, "The Technical Department," paper presented to Calco student trainees, April 27, 1946, 14. King sometimes recycled texts from various papers, the auramine story included, which reappeared, for example, in "Some Items that Contribute to the Successful Management of a Chemical Manufacturing Operation," given to supervisors of E. R. Squibb & Sons, November 23, 1948, 12. King Papers, MS 429, Dartmouth College Library. These documents are excellent sources of information on modifications to processes.
14. H. C. Halsted, "Medical Progress," *Bound Brook Diamond* 22, no. 23 (June 13, 1957): 4.
15. W. R. Bradley, "Cyanamid's Industrial Hygiene Program," *Industry and Power* 60 (January 1951): 98-9.
16. Arthur F. Mangelsdorff, "Methemoglobinaemia–Recognition, Treatment, and Prevention," *Industrial Medicine and Surgery* 21 (1956): 395–98.
17. Erwin Klingsberg to author, telephone, October 28, 2002. Klingsberg was recounting information given to him by Bound Brook chemist Philip Ruby around 1960.
18. David A. Hounshell and John Kenly Smith Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980* (Cambridge: Cambridge University Press, 1988), 555–72,

esp. 558–66. See also Sellers, *Hazards of the Job,* 193–94. Sellers also provides background information on Robert Kehoe.

19. A. F. Mangelsdorff to H. D. Acaster, July 15, 1947. Copied to V. E. Atkins, E. H. Bart, and D. O. Hamblin, SME/RS.
20. See for example, T. S. Scott, *Carcinogenic and Chronic Toxic Hazards of Aromatic Amines* (Amsterdam: Elsevier, 1962).
21. "Determination of BNA [beta-naphthylamine] in Section E Intermediates." Analytical Section, Bound Brook, report no. 58–314, November 11, 1958, Bound Brook Memorial Library. The presence of beta-naphthylamine was established by infrared spectroscopy.
22. Bound Brook "handled" beta-naphthylamine from around 1937. V. L. King to D. O. Hamblin, December 8, 1938. By the mid-1940s "due to pressure of other work," the amine was purchased from DuPont. Manufacture "in modest quantities" at Bound Brook was resumed during 1947 for a short time. V. L. King, "Beta naphthylamine," July 18, 1947; and King to E. H. Bart, December 11, 1947. Then it was purchased, again from DuPont, until about 1953, when manufacture ceased due to the concerns over bladder cancer. Bound Brook then dropped all dyes made from this intermediate. On January 4, 1954, M. L. Kessler distributed copies at Bound Brook of the item "Incidence of Bladder Tumors in British Dye Industry Studied" that appeared in *Chemical and Engineering News,* December 28, 1953, and is described in Scott, *Carcinogenic and Chronic Toxic Hazards,* 42–45. This followed a five-year study by the Association of British Chemical Manufacturers. The conclusion was that the probability "of death from tumor of the bladder is about 30 times greater for persons involved in manufacture and use of alpha-naphthylamine, beta-naphthylamine, and benzidine, than the general population." Benzidine was manufactured at Bound Brook probably until the early 1940s, and then occasionally, until about 1954. "Technical Committee Minutes, Department E, January 19, 1954," 7, Bound Brook Memorial Library.
23. Roderick H. Horning, "Dye industry ad hoc committee in NIOSH project minutes," for meeting held on June 16, 1976. Earlier reviews of carcinogenic dyes include R. Schoental, "Note on the Carcinogenecity of Azo-dyes," draft typescript conference paper [1951], SME/RS.
24. S. M. Gerber to ad hoc Dyes Ecology Committee, "Proposed presentation outline for meeting," January 28, 1977; and memorandum for the ad hoc Dyes Ecology Committee regarding "Implementation of Environmental Legislation," Cleary, Gottlieb, Steen & Hamilton, April 12, 1977, SME/RS. The latter discusses EPA's implementation of the Toxic Substances Control Act [TSCA] and OSHA/NIOSH regulatory programs that were of interest to the dye industry: "EPA is already of the view that the manufacture and distribution of dyes may pose substantial environmental and health problems. Benzidine is one of the few chemicals for which EPA has promulgated toxic pollutant regulations under the Water Act and EPA has indicated it is considering further regulation of benzidine under TSCA. NIOSH has underway a program to develop recommended OSHA standards for 58 suspected carcinogens, including 23 dyes and dye intermediates of some commercial significance. Of the nine classes of chemicals containing known carcinogens and

mutagens, aromatic amines and azo dyes were listed as one such class." By the early 1990s, very few of the substances covered by the TSCA had been assessed. See Sellers, *Hazards of the Job*, 237.

25. One outcome was A. W. Burg and M. C. Charest, *Azo Dyes: Evaluation of Data Relevant to Human Health and Environmental Safety* (Arthur D. Little, Inc., for DETO, July 1980). Other chemical industry organizations with similar agendas included the American Industrial Health Council and the Chemical Industry Institute of Toxicology.
26. William J. Storck, "Tough Year May be Ahead for Chemical Labor," *Chemical and Engineering News* 57 (January 1, 1979): 10–11. See also "Wage Guidelines Spark Strike at Cyanamid," *Chemical and Engineering News* 56 (December 11, 1978): 7. The prevalence of occupationally induced cancers in New Jersey led Dr. Irving J. Selikoff of Mount Sinai Medical Center, New York, to give a new nickname, "Cancer Alley," to the Garden State. The strike was the first in the chemical industry in response to President Carter's newly introduced 7 percent wage guidelines. Bound Brook was kept in operation by supervisory personnel and plant technical people, including chemists and chemical engineers.
27. "American Cyanamid," entry in Thomas Derdak, ed., *International Directory of Company Histories* (Chicago: St. James Press, 1988), vol. 1, 300–2, on 301.
28. Howard Hu was later appointed professor of occupational and environmental medicine at the Department of Environmental Health, Harvard.
29. Neil M. Mackenzie, "Cyanamid Editorial Considered Unfair," *Courier–News*, January 15, 1979.

CHAPTER TEN

1. Gerard A. Forlenza to author, telephone, April 23, 2002.
2. "The Bound Brook Plant and Effluent Treatment Facilities. February 1975. American Cyanamid Company. Bound Brook Plant." Prospectus with introduction by B. H. Loper, president, Organic Chemicals Division, to the Executive Committee, February 21, 1975, and attachments, numbered consecutively. The main body of this prospectus consists of sections dealing with effluent treatment facilities, financial data and endorsements, and a plant rehabilitation program. Appendices deal with effluent treatment, Bound Brook plant viability, and financial data. These extracts are from "Section IV Appendix. Effluent Treatment Facility," 40–41 (hereafter Loper).
3. Loper, 43–45.
4. Ibid., 45–48. Excess waste activated sludge from the existing secondary-treatment clarifiers "will be thickened … and dewatered to a 14% solids cake on two rotary drum vacuum filters. The dewatered sludge will then be incinerated and the ash disposed of by trucking to an approved sanitary landfill."
5. Ibid., 51.
6. Ibid., 51, 52.

7. Ibid., 106. On subsequent review, as described in chapter 7, these proposals were amended in anticipation of a growth in pigment manufacture.

CHAPTER ELEVEN

1. Jay Leavitt to author, email, April 21, 2002.
2. William B. Hardy to author, email, May 2, 2002.
3. David A. Hounshell and John Kenly Smith Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980* (Cambridge: Cambridge University Press, 1988), 582–84.
4. William B. Hardy to author, email, May 2, 2002. Hardy points out that Bound Brook, "had an early start in the plastics field [but] failed to pursue the area vigorously," by building, for example, on the polymer expertise of Roy Kienle. At the end of the 1980s, Dow had moved to second place, after DuPont, in the league of U.S. chemical corporations. American Cyanamid was thirteenth. For the ascent of General Electric as a major producer of polymers and other chemicals, see Jerome T. Coe, *Unlikely Victory: How General Electric Succeeded in the Chemical Industry* (New York: American Institute of Chemical Engineers, in association with Chemical Heritage Foundation, 2000).
5. This was a core message in the "agility" preaching project, the Agility Forum, at Lehigh University, directed by Steven L. Goldman during 1995–97. It was a corollary to the gospel of an open information environment, and broad knowledge-sharing across a company and among collaborating companies. For a more explicit discussion, see Goldman's essay, "The Social Captivity of Engineering," in *Critical Perspectives on Nonacademic Science and Engineering*, ed. Paul T. Durbin (Research in Technology Series, vol. 4) (Bethlehem, Pa.: Lehigh University, 1991), 121–45, together with his more theoretical "Philosophy, Engineering, and Western Culture," in *Broad and Narrow Interpretations of Philosophy of Technology*, ed. Paul T. Durbin (Dordrecht: Kluwer, 1990), 125–52.
6. Isaiah Von to author, email, July 12, 2001. Von's reference to the pharmaceutical firms is a reminder of their proliferation in north New Jersey, especially from 1930, when Calco made great strides in this business. They included Merck at Rahway (1902), and Hofmann-La Roche at Nutley (1928–29). Merck and Maltbie Chemical Co., at Newark (since 1905), quickly followed Calco as manufacturers of sulfa drugs. In 1934, the Schering Corporation (founded 1928; since 1971 Schering-Plough, of Kenilworth, New Jersey) moved from New York to Bloomfield, and three years later the Swiss CIBA opened a pharmaceutical facility at Summit, followed by a research center in 1940. E. R. Squibb & Sons had been in New Jersey since shortly after 1910, and added new research facilities in 1938. From 1930, Jersey City was home to the Bilhuber-Knoll Coporation, and E. Bilhuber, Inc., which erected modern facilities, including research laboratories, in 1938. Bound Brook's Research Department (1927), however, preceded most similar research laboratories in the American chemical and pharmaceutical industries, such as that of Merck, opened during 1930–33. The trend has continued in recent times with the move of the R&D centers of the Swedish Pharmacia (after merging with Upjohn) and the

French-German Aventis to New Jersey, in 1995 and 1999, respectively. In 1975, Ben Loper stated that the Bound Brook facility had additional capacity for expansion, probably from various anticipated closedowns.

CHAPTER TWELVE

1. Stewart Lee Udall, "The Conservation Challenge of the Sixties," the Horace M. Albright Conservation Lectureship, School of Forestry, University of California, Berkeley, April 19, 1963.
2. Elinor Langer, "A View from the Bridge: Politics No Picnics on Banks to Pollution; Strong Federal Agency is Likely," *Science* 142 (1963): 566–7.
3. John K. Smith Jr., "Turning Silk Purses into Sows' Ears: Environmental History and the Chemical Industry," *Enterprise and Society* 1 (2000): 785–812, on 788. This paper discusses the roles of both domestic and industrial wastes, and cost considerations, particularly from the perspective of turnover and research budgets, and is a useful introduction to federal, state, and industry approaches from the 1930s.
4. Useful surveys of legislation and laws in the United States until 1970 are John A. Blatnik, "History of Federal Pollution Control Legislation," in *Industrial Pollution Control Handbook,* ed. Herbert F. Lund (New York: McGraw-Hill, 1971), 2-1–2-17, and Jerome Wilkenfeld, "History of State and Local Pollution Laws," idem., 3-1–3-17.
5. David A. Alcorn (Crompton & Knowles Corp.), "U.S. Dye Manufacture: An Important Resource for the U.S. Textile Industry," *Textile Chemist and Colorist* 22, no. 12 (December 1990): 9–11.
6. Crompton & Knowles purchased most of DuPont's remaining dye-making technology during 1980–81.
7. Two important studies relevant to chemical industry in the 20th century are Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste Before EPA* (Austin: University of Texas Press, 1996), and Martin Forter, *Farbenspiel: Ein Jahrhundert Umweltnutzung durch die Basler chemische Industrie* (Zurich: Chronos Verlag, 2000). See also Hugh S. Gorman, *Redefining Efficiency: Pollution Concerns, Regulatory Mechanisms, and Technological Change in the U.S. Petroleum Industry* (Akron: University of Akron Press, 2001).
8. See, in particular, Ashish Arora, Ralph Landau, and Nathan Rosenberg, eds., *Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry* (New York: Wiley, 1998).
9. L. F. Haber, *The Chemical Industry During the Nineteenth Century. A Study of the Economic Aspect of Applied Chemistry in Europe and North America* (Oxford: Clarendon Press, 1958; second edition 1969); Haber, *The Chemical Industry, 1900–1930: International Growth and Technological Change* (Oxford: Clarendon Press, 1971); and Williams Haynes, *American Chemical Industry,* 6 vols. (New York: D. Van Nostrand, 1945–54).
10. See contributions to special issue of *Ambix* 49 (March 2002). A useful overview is

Kian Esteghamat, "Structure and Performance of the Chemical Industry under Regulation," in *Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry*, 341-77. See especially the table of environmental measures on 342-3.

11. The U.S. Public Health Service used the term refractory to cover all materials not removed from water by conventional methods of treatment. See, for example, James R. Marshall, "Today's Wastes: Tomorrow's Drinking Water?" *Chemical Engineering* 69 (August 6, 1962): 107-10.
12. Anthony S. Travis, "Poisoned Groundwater and Contaminated Soil: The Tribulations and Trial of the First Major Manufacturer of Aniline Dyes in Basel," *Environmental History* 2 (July 1997): 343-65; Travis, "Contaminated Earth and Water: A Legacy of the Synthetic Dyestuffs Industry," *Ambix* 49 (2002): 21-50; Sarah Wilmot, "Pollution and Public Concern: The Response of the Chemical Industry in Britain to Emerging Environmental Issues, 1860-1901," in *The Chemical Industry in Europe, 1850-1914: Industrial Growth, Pollution, and Professionalization*, ed. Ernst Homburg, Anthony S. Travis, and Harm G. Schröter (Dordrecht: Kluwer, 1998), 121-47; and Arne Andersen, "Pollution and the Chemical Industry: The Case of the German Dye Industry," idem, 183-200. See also Hugh Gorman, "Manufacturing Brownfields: The Case of Neville Island, Pennsylvania," *Technology and Culture* 38 (1997): 539-74.
13. The solubility of oxygen in water in equilibrium with the atmosphere at 25°C is 8.7mg/l. The oxygen depletion is caused by the presence in surface waters of oxidizable substances, including organic industrial effluent. This creates a sag in the concentration of dissolved oxygen. Generally, the organic material present in a stream is oxidized by bacterial action to afford simple compounds, such as carbon dioxide and water. However, the extent of oxidation varies, according to the nature of the effluent. Fish leave a river or die if the amount of dissolved oxygen is too low for their survival. The dissolved oxygen content of surface waters should be sufficient to support normal aquatic life. The degree of oxygen consumption is the Biological (or Biochemical) Oxygen Demand (BOD). The standard procedure for determining BOD is a five-day test carried out at 20°C. The BOD is determined as parts per million by weight. For a given substance, the sample is diluted, then seeded with suitable bacteria. The amount of dissolved oxygen is measured before and after the five-day period. Sometimes it is necessary to acclimatize bacteria to a chemical before it can be degraded. Some compounds are totally resistant to bacteria, and the BOD is thus zero. There is often a strong correlation between such compounds and toxicity. Another index is Chemical Oxygen Demand (COD), determined originally by using permanganate to oxidize organic matter. Permanganate has been replaced by dichromate. These oxidants break down substances not attacked by oxygen alone, including the refractory organic compounds.
14. William Howarth and Donald McGillivray, *Water Pollution and Water Quality Law* (Crayford, Kent: Shaw & Sons, 2001), 19-22.
15. Carroll Pursell has completed an important contribution to the history of regulatory developments in the U.S. Army Corps of Engineers (in draft). Chapter one covers the 1899 Rivers and Harbors Act (the Refuse Act). Chapter two deals with the

regulatory program in the 1960s and 1970s. I am grateful to Martin Reuss for providing me with access to this document.

16. *Bound Brook Diamond* 22 (June 13, 1957): 5.
17. Transcript of "Conference on Pollution of the Interstate Waters of the Raritan Bay and Adjacent Waters, First Session. Called by the Surgeon General, Public Health Service, under the Federal Water Pollution Control Act. The Public Health Service, U.S. Dept. of Health, Education, and Welfare, the Interstate Sanitation Commission and the State Water Pollution Control Agencies of New Jersey and New York. New York, August 22, 1961," 1. In the 1920s, following extensive investigations, the State of New York restrained New Jersey from discharging sewage and trade waste originating in the Passaic Valley watershed into Upper New York Bay. Earlier investigations had been carried out by the Metropolitan Sewerage Commission of New York, as reported in W. M. Black and E. B. Phelps, *Report Concerning the Location of Sewer Outlets and the Discharge of Sewage into New York Harbor, Submitted to the Board of Estimate and Apportionment of the City of New York* (New York, March 23, 1911).
18. The Pillar of Fire is an evangelical Christian organization, founded in 1910 by Bishop Alma White, that held annual encampments at its Zarapath site, next to the Delaware and Raritan Canal, west of Bound Brook. Its temple was originally located in East Main Street, Bound Brook. The building still stands, though it is no longer occupied by the organization. Bishop White was author, among other works, of the anti-Catholic *Klansmen: Guardians of Liberty* (1926).
19. *Public Works* 60 (1929): 335.
20. Willem Rudolfs and I. O. Lacy, "Effect of Dye Manufacturing Waste Upon Sludge Digestion," *New Jersey Agricultural Experimental Station Bulletin* 20 (1929): 486. Rudolfs, a Dutch-born biochemist, joined the experimental station in 1921, and from 1922 until retirement in 1952 was chief of water and sewage research. During 1926–52, he was professor and chairman of the department of sanitation at Rutgers University. He was involved in Raritan River pollution studies in 1927–28, 1937–38, 1940–41, and 1951, as reported in the Federation of Sewage Works Associations' *Sewage Works Journal* and elsewhere.
21. The Federation of Sewage Works Associations was forerunner of the Federation of Sewage and Industrial Wastes Associations (1950), which in turn became the Federation of Water Pollution Control Associations (1960), often referred to as the Water Pollution Control Federation, and renamed Water Environment Federation in October 1991. *Sewage Works Journal* became, successively, in 1950, *Sewage and Industrial Wastes,* in 1960, *Journal of the Water Pollution Control Federation (Journal WPCF);* and in 1991, *Water Environment Research.* The Water Environment Federation's Willem Rudolfs Medal for Outstanding Accomplishments by an Industrial Waste Control Employee was originally established in 1949 as the Industrial Wastes Medal, and renamed in 1966.
22. "Conference on Sewers," *Bound Brook Chronicle,* April 11, 1930.
23. *Bound Brook Chronicle,* April 18, 1930.
24. Papers of George Smith, chairman, Middlesex County Planning Board, item dated April 29, 1948. Leonard Metcalf and Harrison P. Eddy established their consultancy

partnership in 1907, specializing in sewerage, water supply, and drainage. Metcalf died in 1926, at which time Eddy became senior partner. They were authors of the three-volume *American Sewerage Practice* (New York: McGraw-Hill, 1914–15), which in its most recent edition is *Wastewater Engineering: Treatment, Disposal and Reuse* (New York: McGraw-Hill, 1991).

25. Willem Rudolfs, "Stream Pollution in New Jersey: Importance of Industrial Waste," *Industrial and Engineering Chemistry* 28 (1936): 1294–95, on 1294. From a paper presented before the Division of Water, Sewage, and Sanitation Chemistry, American Chemical Society, at the 92nd general meeting held in Pittsburgh, September 1936. (Reflecting broader interests, from the 1980s the division has been known as the Division of Environmental Chemistry.) In November 1944, Rudolfs gave one of the papers at the first Purdue Industrial Waste Conference. Investigations into river pollution were conducted in various states during the 1930s. As in Europe manufacturers claimed that domestic sewage was the greatest threat to surface waters, and that trade waste actually had a beneficial antiseptic effect on municipal waste. Attempts to introduce comprehensive U.S. federal legislation generally floundered as a result of disputes over the regulatory rights of federal and state agencies. See also Craig E. Colton, "Creating a Toxic Landscape: Chemical Waste Disposal Policy and Practice, 1900–1960," *Environmental History Review* 18 (1994): 85–116, esp. 96. Colton provides a very useful summary of the practices and responses of Allied Chemical, Dow, DuPont, Monsanto, and Hooker Chemical, as well as the work of the Manufacturing Chemists' Association Stream Pollution Committee.
26. H. Heukelekian, introduction to papers on "Purifying Chemically Polluted Waters," *Industrial and Engineering Chemistry* 48 (September 1956): 1403. These papers were given before the Division of Water, Sewage, and Sanitation Chemistry, American Chemical Society, at the 128th meeting, Minneapolis, September 1955. The New Jersey Water Environment Association's award for industrial waste control is named in honor of Heukelekian.
27. "In general there is a complete and spontaneous mobilization of biological populations working in a smooth integrated assemblylike fashion. The details regarding the succession of the organisms, effects of one group on the activities of the others, sequence, interactions, and interdependence of one reaction on another, and intermediate and alternate pathways are unknown to us. The result is that with present information we are not able to exercise complete control on the processes, nor approach difficulties except by empirical methods." H. Heukelekian and M. C. Rand, "Biochemical Oxygen Demand of Pure Organic Compounds: A Report of the Research Committee, FSIWA [Federation of Sewage and Industrial Wastes Associations]," *Sewage and Industrial Wastes* 27 (September 1955): 1040–53. For industrial products, see also F. J. Ludzack and M. B. Ettinger, "Chemical Structures Resistant to Aerobic Biochemical Stabilization," *Journal WPCF* 32 (November 1960): 1173–1200.
28. Minutes of the Board of Health of the Township of Bridgewater, October 12, 1935.
29. Idem., November 9, 1935.
30. C. E. Mensing, R. L. Cassell, C. H. Bean, H. C. Spencer, and V. L. King, "Calco's

New Waste Treatment Plant," *Chemical and Metallurgical Engineering* 48 (March 1941): 84–88, on 85. See also review by Paul D. Haney, *Sewage Works Journal* 13 (1941): 1009–10. Spencer was probably the biochemist Howard Carmac Spencer, specialist in industrial hygiene and toxicology, who joined Dow at Midland in 1937.

31. Minutes of the New Jersey Department of Health, December 14, 1937, with reference to letter of December 13, 1937, from R. Watson to Dr. Mahaffey, TSME.
32. Minutes of the New Jersey Department of Health, January 11, 1938, TSME.
33. Ibid., March 8, 1938, TSME.
34. Calco was ordered to "neutralize all free acidity ... effect a reduction of color or turbidity, or both, so that wastes after dispersion into any of the waters of the Raritan River ... not more than 1,000 feet below the point of discharge from the waste treatment plant, [shall] not substantially discolor or alter the natural color, or add to the turbidity."
35. Minutes of the New Jersey Department of Health, February 8, 1939, TSME.
36. "Calco Ready to Cooperate: Col. Weeks Points to Engineering Problems at Board Meeting," *Bound Brook Chronicle,* January 14, 1939.
37. "Praise Calco on Pollution: State Board Reports on Progress Made to Date," *Bound Brook Chronicle,* April 21, 1939.
38. Resolution of New Jersey Department of Health, April 14, 1939.
39. Chemist and metallurgical engineer John Van Nostrand Dorr founded the Dorr Company in 1910 (as Dorr Cyanide Machinery Co.), to develop equipment for mining industry processes, including solid-liquid separation, sedimentation, and flotation. Subsequently, and among many other activities, Dorr's firm became involved in waste treatment, based on the Dorr classifier, Dorr thickener, and Dorr agitator. In 1955, Dorr merged with Oliver United Filters to create Dorr-Oliver, Inc., of Stamford, Connecticut. Dorr-Oliver became part of the GL&V corporation in 1999, from then known as GL&V/Dorr-Oliver. E. B. Besselievre was one of the noted waste-treatment experts associated with the Dorr Company in the 1930s.
40. An illustration of the Bound Brook Dorr unit appears in M. C. Whitaker, "The Work of the [Perkin] Medalist [John Van Nostrand Dorr]," *Industrial and Engineering Chemistry* 33 (1941): 361–65, on 362. Excess carbonate was pumped to a storage basin of 10-million-gallon capacity (impoundment 24). Additional impoundments (numbers 13 and 19), excavated adjacent to the neutralization lagoon, were also utilized for carbonate storage.
41. V. L. King, R. F. Bann, R. C. Conn, R. E. Lester, J. E. Stanley, and D. Tarvin, "Relation of Stream Characteristics to Disposal of Chemical Manufacturing Effluents," *Sewage Works Journal* 21 (1949): 534–49, quoting from 546. Donald Tarvin, who was awarded the Ph.D. in water and sanitary chemistry from Illinois State University in 1933, worked successively as chemist and bacteriologist for the Illinois Water Survey, analytical chemist for the Tennessee Valley Authority, and, during 1939–44, research chemist at General Chemical Company, New York. He was employed by Calco during 1944–53, mainly to work on wastewater treatment, and held a New Jersey operator's license for the Bound Brook wastewater treatment plant. See Donald Tarvin, "Chlorine Demand of Waste from a Chemical Plant," *Sewage and Industrial Wastes* 24 (1952): 1130–34. From 1953–72, he was chief

chemist and subsequently associate of consulting engineers Floyd G. Brown & Associates, of Marion, Ohio. See the entry "Donald Tarvin," in "Tarvin Life," 5, http://www.tarvin family.org/lifeline/2000-2/5.html (accessed December 21, 2001).

42. Mensing, Cassell, Bean, Spencer, and King, "Calco's New Waste Treatment Plant," on 84.
43. *Bound Brook Chronicle,* November 14, 1940.
44. King, Bann, Conn, Lester, Stanley, and Tarvin, "Relation of Stream Characteristics to Disposal of Chemical Manufacturing Effluents," 536.
45. V. L. King and R. J. Jenny, "Don't Throw Troubles to the Winds," *Chemical Engineering* 56 (March 1949): 107–11.
46. V. L. King, C. H. Bean, R. E. Lester, and Willem Rudolfs, "Water Treatment at the Calco Chemical Division," *Chemical and Engineering News* 21 (1943): 1046–49. Originally presented to the Division of Water, Sewage and Sanitation Chemistry, American Chemical Society, Detroit, April 1943.
47. For Powell and the MCA see Craig E. Colton, "Creating a Toxic Landscape: Chemical Waste Disposal Policy and Practice, 1900–1960," esp. 97–8, 101. The name of the MCA was later changed to Chemical Manufacturers' Association.
48. Sheppard T. Powell, "Creation and Correction of Industrial Wastes," *Industrial and Engineering Chemistry* 39 (1947): 565–68, on 565.
49. Ibid., 567.
50. King, Bann, Conn, Lester, Stanley, and Tarvin, "Relation of Stream Characteristics to Disposal of Chemical Manufacturing Effluents," on 534–5, and 549. For support, from R. D. Hoak (Mellon Institute of Industrial Research), see "Disposal of Chemical Manufacturing Wastes–A Discussion," 549–52.
51. "Chemists Inspect Processes at Calco," *Bound Brook Chronicle,* May 5, 1947.
52. Rudolfs's results on stabilization of sludge appear in King, Bann, Conn, Lester, Stanley, and Tarvin, "Relation of Stream Characteristics to Disposal of Chemical Manufacturing Effluents," 545.
53. Mohlman gained his Ph.D. in chemistry from the University of Illinois in 1916, working with Professor Edward Bartow. In 1914 they undertook experiments on aeration with activated sludge, improving on work that Bartow had observed in Manchester, England. Mohlman's first posts were as chemist to the Illinois State Water Survey and New Haven Experimental Station of the Connecticut Department of Health. He gave one of the papers at the first Purdue Industrial Waste Conference in 1944.
54. F. W. Mohlman, "Waste Disposal: Waste Disposal as a Factor in Plant Location," *Chemical Engineering Progress* 46 (1950): 321–7, on 324–5.
55. "Pollution Research Pushed," *Chemical Engineering* 61 (January 1954): 122–24, on 124.
56. F. W. Mohlman, "Chemistry and Sewage Treatment," *Chemical Progress During the 75 Years of the American Chemical Society* (Washington, D.C.: American Chemical Society, 1951), 111–14, on 113.
57. For early accounts of pollution of wells and groundwater, see articles in *Journal of the New England Water Works Association* 53 (1939): 307–27. See also H. L. Jacobs, "The Industrial Approach Toward Waste Treatment and Stream Pollution

Abatement," *Proceedings of the 10th Annual Water Conference, Engineers Society of Western Pennsylvania* (1949), 127–33. This paper deals mainly with DuPont. The discussion includes chromium and cyanide pollution of groundwater by seepage from a waste lagoon.

58. See, for example, the papers from a British conference on groundwater pollution: H. A. Swenson, "The Montebello Incident," *Proceedings of the Society for Water Treatment and Examination* 11, part 2 (1962): 84–88, and Morris Deutsch, "Phenol Contamination of an Artesian Glacial-drift Aquifer at Alma, Michigan, U.S.A.," idem, 94–100.
59. These were often included with other "deleterious substances." Thus for "the Raritan River in New Jersey, the State Department of Health has promulgated effluent standards for two zones, both of which require that the 'effluent be free of noticeable floating solids.'" Jack Edward McKee, *Report on Oily Substances and Their Effects on the Beneficial Uses of Water* (Sacramento: State Water Pollution Control Board, 1956), 20. This publication appeared just before the widespread changeover to instrumental analysis of waste waters, and summarizes the varieties of wet methods available, as well as three instrumental methods, infrared and ultraviolet spectroscopy, and mass spectrometry, of which the latter then held out the greatest promise. During the 1960s, gas chromatography became the method of choice, particularly for separation of components in a mixture, though relying on other methods, particularly mass spectrometry, for purposes of identification.
60. E. L. Knoedler and S. H. Babcock Jr., "Industrial Wastes: Pharmaceutical and Biological Plants," *Industrial and Engineering Chemistry* 39 (1947): 578–82, on 578.
61. Harold R. Murdock, "Industrial Wastes," *Industrial and Engineering Chemistry* 43 (June 1951), 99A–102A, on 99A.
62. John Ludden Jr. (Calco Chemical Division, Willow Island), and John F. Vogler (sanitary engineer, Bound Brook), "Water Conservation in a Chemical Plant," *Sewage and Industrial Wastes* 24 (1952): 1377–81.
63. Forter, *Farbenspiel: Ein Jahrhundert Umweltnutzung durch die Basler chemische Industrie,* 94–96.
64. "Calco Officials Claim Effluent Made Harmless Before Raritan Discharge," *Bound Brook Chronicle,* August 21, 1947.
65. Daniel Bergsma to W. S. Weeks, July 16, 1952, TSME.
66. D. M. Aumack, "Technical Committee Minutes, Department E, September 29, 1953," 6. Bound Brook Memorial Library.
67. This testing ground for wastewater treatment procedures had been created by the Massachusetts Board of Health in 1887, and for many years was a leader in studies on water research, including the action of microorganisms in sewage treatment. It was followed in 1913 by the U.S. Public Health Service stream investigation station in Cincinnati (from 1948 known as the Environmental Health Center, which in 1954 became the Robert A. Taft Sanitary Engineering Center). For early biological treatment processes, see James E. Alleman, "The History of Fixed-Film Wastewater Treatment Systems," http://ce.ecn.purdue.edu/~alleman/w3-class/456/article/article-biofilmhistory.html (accessed January 21, 2001).
68. John F. Vogler, "Treating Organic Wastes on Experimental Trickling Filters. I.

Fundamental Design Considerations," *Water and Sewage Works,* July 1954, 316–20; George E. Hendee Jr. (design engineer, Power and Utilities Department, Bound Brook), "II. Pilot Plant Design Consideration," idem, 320–23; Alfred B. Cherry (sanitary engineer, Bound Brook), "III. Operating Considerations," idem, 366–68; and Louis A. Tucci (sanitary engineer, Lederle Laboratories Division, Pearl River), "IV. Biological Considerations in Trickling Filters," idem, 368–72.

69. "Calco Out: Authority Planning Limited Sewer," *Bound Brook Chronicle,* June 19, 1952.
70. S. T. Powell and Whitman, Requardt & Associates, "Collection, Treatment and Disposal of Municipal and Industrial Wastes and Compensating Water in Somerset County, New Jersey" (April 1953). The consulting engineering partnership Whitman, Requardt & Associates was established in 1943. Its forerunners were Norton, Bird and Whitman, founded in 1915 as a consultancy in water and wastewater, and Whitman, Requardt and Smith (1925).
71. "Pollution Research Pushed," *Chemical Enginering* 61 (1954): 122–24. Another consultant to American Cyanamid at this time was Charles E. Renn of Johns Hopkins University.
72. D. M. Aumack and G. W. Hedden, "Technical Committee Minutes, Department E, March 9, 1954," 4. On February 16, Aumack, Mackenzie, and Kladivko were authorized to decide on which high BOD content mother liquors were to be sampled and tested for BOD. "Technical Committee Minutes, Department E, February 16, 1954," 1. Bound Brook Memorial Library.
73. "Technical Committee Minutes, Department E, September 29, 1953, 5–6," and "Technical Committee Minutes, Department E, May 18, 1954," 2. Bound Brook Memorial Library.
74. W. Wesley Eckenfelder Jr., professor of civil engineering at Manhattan College and a consulting process engineer, was a leading U.S. expert on bio-oxidation of process wastes. He had worked at General Chemical as a control chemist, and at Atlantic Refining as a sanitary engineer. Activated sludge treatment was introduced in the United States during 1916–26, at Houston, Milwaukee, Pasadena, and Indianapolis. For Dow, see Craig E. Colton, "Creating a Toxic Landscape," 102.
75. "Pollution of River Scored by Lydecker," *Bound Brook Chronicle*, January 21, 1957.
76. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50, 1915–1965* (Bound Brook: American Cyanamid Company, 1965), 46. See also "American Cyanamid Breaks Ground for New 4 Million Sewage Plant," *Bound Brook Chronicle*, March 28, 1957, and *New York Times,* March 28, 1957.
77. "Work on Cyanamid's Sewage Plant Right on Schedule," *Bound Brook Chronicle,* November 28, 1957.
78. "Facility is 'One of Most Outstanding Projects of Its Kind in U.S.' Says Acting Governor," *Bound Brook Diamond* 23, no. 15 (June 13, 1958): 3. Most of this issue was devoted to the opening of the waste treatment plant. Details were included of a new incinerator, that enabled discontinuance of open burning of rubbish and waste at the facility's dumps. The opening dedication and seminar were reported in the

Courier-News, June 4, 1958, and *The Democrat,* June 5, 1958. See also "Cyanamid Hires Firm to Design Sewage Facilities," *Bound Brook Chronicle,* July 26, 1956.

79. Around this time American Cyanamid began promoting the use of rhodamine B, detected instrumentally at concentrations of less than one part per million, as a tracer for use in pollution studies. "Public Health Detectives Use Dyes to Solve Water Troubles," *Leather Lines,* April 1965, 4, and *Dyelines,* April 1965, 2. One use was in study of sewage entering Raritan Bay, "presumably that dumped raw by the City of New York into the Upper Bay."
80. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50,* 46.
81. Improvements in liquid waste treatment followed close monitoring of the effluents. A novel study in 1958 of the retention time during the settling process employed radioactive tracers to establish the rate of flow through a settling tank at Bound Brook. Though designed to retain effluent for two to three days, "these experiments measured radioactivity after only 2 to 5 hours at the exit ports, and thus showed that the settling process was not as good as it should have been." *Research Division News,* December 1958, 24–5.
82. "Cyanamid Hires Firm to Design Sewage Facilities," *Bound Brook Chronicle,* July 26, 1956.
83. *Bound Brook Diamond* 28 (July 31, 1963). On October 3, 1957, the *Messenger–Gazette,* ran an item under the heading "Major Milestone," announcing the signing of the contract between the SRVSA and American Cyanamid. See also "Somerset–Raritan Sewer Plan Revived," *Bound Brook Chronicle,* November 15, 1956.
84. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50,* 46.
85. Ibid.
86. Sheppard T. Powell and James C. Lamb III, "Industrial and Municipal Cooperation for Joint Treatment of Wastes. I. Industry Approach and Position," *Sewage and Industrial Wastes* 31 (1959): 1044–52. This was originally presented to the 31st annual meeting, Federation of Sewage and Industrial Wastes Associations, Detroit, Michigan, October 6–9, 1958. The authors drew attention to the diversity of waste treatment facilities at American Cyanamid sites, where "there is almost every conceivable general arrangement for disposal of industrial wastes. At many locations, wastes are treated in company-owned facilities and discharged directly to receiving bodies of water without any connection with municipal systems. At other plants, wastes are discharged to municipal sewage handling systems without pre-treatment or after physical, chemical, or biological treatment, depending on the circumstances in each case. Thus, it may be seen that the Company has no firmly fixed policy for or against discharge of plant wastes into municipal systems" (1045).
87. "Conference on Pollution of the Interstate Waters of the Raritan Bay and Adjacent Waters, First Session. Called by the Surgeon General, Public Health Service, under the Federal Water Pollution Control Act … New York, August 22, 1961."
88. Affidavit of A. Bruce Pyle, December 1962.
89. R. S. Shaw to N. E. Curtiss (attorney at American Cyanamid, Wayne), April 14, 1965.
90. R. P. Kandle, M.D., Commissioner, NJDH, Trenton, to G. W. Hedden, Bound Book, June 30, 1966.

91. *Cyanamid Organic Chemicals Division. Bound Brook Plant 50*, 48.
92. Ibid.
93. G. W. Hedden to R. P. Kandle, July 5, 1967, TSME.
94. E. R. Segesser, to R. J. Sullivan, NJDH, July 24, 1967, TSME.
95. F. Richardson to S. L. Udall, June 2, 1967, TSME.
96. Transcript of governmental conference, "Data Memorandum for Conference with Director Paul De Falco, Jr. (Project Director, Federal Pollution Control), Raritan Arsenal, Building no. 10, October 3, 1967, at 10:00 am. Re: Secretary Udall of the Interior Dept., U.S. Government has requested Paul De Falco, Jr. ... to confer with our group, in connection with our request to him, to have study made of the future use of the Raritan River."
97. Ibid. "This right of Calco to withdraw 29 mgd is still being exercised ... in dry seasons on the river when the flow sometimes fell short of 30 mgd. No reason can now be urged by Calco why they should not return their 29 mgd to the river reasonably pure, as it is on the take-in." For an account of how the disposal of industrial waste impacted on riparian law in the United States until the early 20th century see Jouni Paavola, "Water Quality as Property: Industrial Water Pollution and Common Law in the Nineteenth Century United States," *Environment and History* 8 (2002): 295–318.
98. "Objections to Presently Proposed Plans of Middlesex County Sewerage Authority to Enlarge its Sayreville Plant, October 3, 1967."
99. "The Bound Brook Plant and Effluent Treatment Facilities. February 1975. American Cyanamid Company. Bound Brook Plant." Prospectus with introduction by B. H. Loper, president, Organic Chemicals Division, to the Executive Committee, February 21, 1975, 40.
100. Quoted by Arthur Brook Crossan III, in his "The Raritan River 1972: A Study of the Effect of the American Cyanamid Company on the River Ecosystem." (Ph.D. diss., Rutgers State University of New Jersey, New Brunswick, 1974.)

CHAPTER THIRTEEN

1. For further discussion, including of the low level of contamination required to produce frothing, see Graham Walton, "ABS Contamination," *Journal of the American Water Works Association* 52 (1960): 1354–62. A good historical survey is William McGucken, *Biodegradable: Detergents and the Environment* (Environmental History Series no. 12) (College Station: Texas A&M University Press, 1991).
2. *Training Course Manual. Water Quality Management* (Cincinnati: U.S. Department of Health, Education, and Welfare/Public Health Service/Division of Water Supply and Pollution Control/Robert A. Taft Sanitary Engineering Center, March 1964), 40–42; and "New Moves in the Wake of the Pesticides-Pollution Squabble," *Chemical Engineering* 73 (January 3, 1966): 32–3.
3. *Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants* (Environmental Protection Agency, 1972); and *Handbook for Monitoring Industrial Wastewater* (Environmental Protection Agency, Office of Technology Transfer,

prepared by Associated Water & Air Resources Engineers, Inc., Nashville, Tennessee, August 1973), section 11-1, "Special Considerations for Municipal Systems," which notes that certain "constituents, such as heavy metals or toxic organics, may actually inhibit the biological organisms at the facility."

4. J. C. Cooper and D. G. Hager (Pittsburgh Activated Carbon Co.), "Pollution: Water Reclamation with Activated Carbon," *Chemical Engineering Progress*, October 1966, 90.
5. Reports of tests and observations made early in 1970 by the NJDH were typical of the ongoing high level of surveillance of Bound Brook. Thus, for example, Arthur Beckwith, laboratory technician, wrote to Richard Delgado, NJDH, on January 6, 1970, reporting test results on samples delivered on December 16 and 17, 1969: "American Cyanamid no. 05191–A bioassay employing undiluted waste was conducted and at the end of 24 hours all fish were dead. The 24 hour TL_m for this waste was found to be 41.5%. The threshold toxicity was about 37% and a decrease of about 10% in survival of the test fish occurred with each increment of 1.4% in the waste concentration." The NJDH Water Pollution Control Program inspection report of April 3, 1970, provides details of investigations carried out by John Cofman, chemical engineer, trainee, and William Savage and Robert Koteh, both field workers, Public Health, on February 5, 16, and 25, and March 2, 3, and 9. On February 5 and 25, and March 3 and 9, four-hour composite samples were taken of effluent, including that entering the Somerset-Raritan Valley Sewerage Authority primary treatment plant, leaving the plant ("the head end of the plant"), entering the Bound Brook aeration basins, and at the chlorine shack, past the final clarifiers. On February 5, 1970, "effluent from the plant is discharged to the Raritan River via Cuckold's Brook from a diffuser system across the Raritan River at Calco Dam. There is a trench off Cuckold's Brook which takes any flow in excess of that which can be handled by the diffusers and leads it to the river downstream of the diffusers. This bypass trench was in use on February 5, 1970 with a flow estimated at four to eight mgd. The effluent stream in Cuckold's Brook was bright green in appearance."
6. Memorandum [writer's name illegible] regarding American Cyanamid, Bound Brook, Bridgewater Township, April 7, 1970.
7. S. L. Gordon, memorandum, June 21, 1970, TSME.
8. "American Cyanamid," S. L. Gordon to R. Sullivan, July 21, 1970, TSME.
9. Memorandum, A. B. Pyle to C. T. Hoffman, August 14 and 17, 1970, TSME.
10. Pyle, memorandum of August 21, 1970, referring to A. B. Pyle, James L. Barker, and John F. Kostrzewa, "The Affect of the Effluent from the American Cyanamid–Somerset-Raritan Valley Sewerage Authority Upon Aspects of the Raritan River as They Relate to its Suitability for Fish. Study period 12/08/65–11/66."
11. C. T. Hoffman to G. W. Hedden, October 16 and 22, 1970, TSME.
12. Hedden to Hoffman, copied to Gordon and Segesser, October 28, 1970, TSME.
13. "Minutes from 293rd meeting ... result of testing by the Bureau of Water Pollution Control and the Division of Fish, Game and Shell Fisheries, New Jersey Department of Environmental Protection," May 17, 1971, TSME.
14. Comments on American Cyanamid report "A Program to Further Characterize the

Effluent from the Secondary Waste Treatment Facility at Bound Brook, New Jersey," May 17, 1971.

15. Memorandum from S. Lubow, May 26, 1971, TSME.
16. "It was intended, therefore, that this survey should examine what effects the effluent from the American Cyanamid plant … is having on fish life … the influence … upon benthic macroinvertebrate … [at] Station No. 5 (N)[north]–Raritan River–about 50 feet below the American Cyanamid Dam on the north side of the river [and] Station No. 5(S)–same as Station 5(N), except on the south side of the river … In contrast to the suitability of the River for support of fish life as depicted at Stations Nos. 1 and 3 [upstream of the Calco dam], there is an abrupt change at Station No. 5 as reflected in the results recorded. At this station, regardless of the fish species employed, their death occurred within 24 hours of their introduction at the test site. Based upon similar results recorded at Stations Nos. 6 and 9, it is apparent that the entire River area encompassed between Stations 5 and 9 [downstream of the Calco Dam] is unsuitable for fish life." D. J. Jacangelo, NJDEP, June 22, 1971. Also "Position of the Division of Fish, Game and Shell Fisheries with Regard to the Effect of the Wastewater Discharge from the Bound Brook Plant of the American Cyanamid–Somerset-Raritan Valley Sewerage Authority upon Water Quality and the Biota of the Raritan River," paper presented by A. Bruce Pyle to the Water Policy and Supply Council, June 21, 1971, TSME.
17. G. W. Hedden to R. J. Sullivan, October 27, 1971, TSME.
18. Figures from the Council on Economic Priorities, New York, 1993.
19. Mercury forms toxic alkyl compounds that through fish are passed into the food chain. Biological accumulation and magnification is typical for methyl mercury and heavy metals. Shellfish in particular tend to concentrate metals, even when they are present in trace amounts in solution.
20. Unsigned and undated affidavit of D. J. Jacangelo, April 1972, TSME.
21. C. M. Pike to G. W. Hedden, copied to S. L. Gordon, May 3, 1972, TSME.
22. "Docket No. C-2883-71; State of New Jersey, Department of Environmental Protection v. American Cyanamid; In the Superior Court of New Jersey, Chancery Division, Somerset County–Order to Show Cause. May 17, 1972." The NJDEP alleged that American Cyanamid violated several water quality standards in releases to the Raritan River. The suit also claimed that solids removed from the treatment process and deposited in on-site lagoons allowed polluting material to leach into the river.
23. "Docket No. C-2883-71; State of New Jersey, Department of Environmental Protection v. American Cyanamid; In the Superior Court of New Jersey, Chancery Division, Somerset County–Verified Complaint. May 17, 1972." Item 2, 4: "[T]he Department has found through investigations and samplings by its representatives that the defendant, since January 1, 1970, is continuing to discharge inadequately, insufficiently and improperly treated industrial waste waters and other polluting matter into the Raritan River causing the receiving waters to fail to conform to the standards of quality established … by the Department. Investigations and results of analyses of departmental sampling are contained in the affidavits attached to this complaint." Item 4, 8: "The Department has never

approved the construction or use of the aforementioned 24-inch sewer line and the defendant is therefore in violation of the aforementioned statutes." The complaint requested the court to order "the defendant to immediately discontinue the discharge of waste materials from the aforementioned sewer pipe." The newly excavated lagoon was also mentioned: "The defendant has constructed and operates a lagoon for the impoundment of sludge generated in its waste treatment facility. This lagoon is located to the north of the defendant's waste water treatment facility ... No permit to construct or operate this lagoon was issued by the Department as required by N.J.S.A. 58:12–3 and 58:11–10."

24. The ruling against American Cyanamid required the corporation to "cease pollution of the Raritan River and its tributaries, being waters of this State, and make such disposition of its industrial wastes or other polluting matter in a manner approved by the Department of Environmental Protection of the State of New Jersey, in accordance with the provisions of N.J.S.A. 58:12–2, 58:12–3, and an amended order of the plaintiff dated January 9, 1967."
25. The effluent standards were: "No noticeable floating solids or foam. Dissolved solids should be not more than a one-third increase in the intake level. No settleable materials or materials causing precipitation, flocculation or other deposition of materials may be added to the streams in quantities that adversely affect the aquatic biota." No color was to be present "which would reduce the depth to which 10% of incident light penetrates the intake river water." Turbidity should not reduce light transmission by more than 10 percent. The range of pH was to be between 6.5 and 8.5. The concentration of toxic and deleterious substances was not to exceed 1/20 of the 96-hour value at any time or place. The 24-hour average concentration of such materials was not to exceed 1/100 of the 96 hour-TL value.
26. The second count of the complaint alleged that American Cyanamid "utilizes a 24-inch reinforced concrete sewer pipe located on its premises which discharges raw industrial waste waters into Cuckold's Brook, a tributary of the Raritan River." The NJDEP "never approved the construction of the 24-inch sewer line and pursuant to NJSA 58:11–10 and 58:12–3 the defendant must receive approval from the State before making any changes, improvements, extensions or alterations to any sewer system." The Court ordered American Cyanamid "to immediately discontinue the discharge of waste materials from the aforementioned sewer pipe." The third count of the complaint alleged that American Cyanamid had constructed a lagoon for the impoundment of sludge for which no permit had been issued: "The defendant owns other lagoons on its premises used for the impoundment of sludge and other waste materials, which lagoons are allowing polluting materials to leach into the Raritan River and Cuckold's Brook, a tributary of the Raritan River."
27. Mortimer M. Gibbons, "Elimination of Tastes and Odors of Industrial Origin from Public Water Supplies," *Industrial and Engineering Chemistry* 24 (1932): 977–82.
28. Between 1950 and 1959, the Elizabethtown Water Co. plant increased by eight-fold its consumption of activated carbon as a result of growing contamination caused by upstream industrial effluent. James Girand, "Plant Improvements and Quality Control at Elizabeth, N.J.," *Journal of the American Water Works Association* 51 (1959): 234–45. See also, "Lower Raritan, South River, Lawrence Brook

Management Area," http://www.njwaters.com/wma/09.htm (accessed December 22, 2001). For the early history of activated carbon see: "Calgon Carbon, Company History," http://www.calgoncarbon.com/calgon/calgonhistory.html (accessed February 7, 2002); and "A Brief History of Activated Carbon and a Summary of its Uses," http://www.cee.vt.edu/program_areas/environmental/teach/gwprimer/group23/achistory.html (accessed February 7, 2002).

29. D. H. Sharp and A. E. Lambden, "Treatment of Strongly Bactericidal Trade Effluent by Activated Charcoal and Biological Means," *Chemistry and Industry* 39 (1955): 1207–16, and D. H. Sharp, "The Disposal of Waste Materials in the Pesticide Industry," *Disposal of Industrial Waste Materials: Papers read at a conference at Sheffield University, 17th–19th April, 1956, with the discussions that followed* (London: Society of Chemical Industry, 1957), 9–15. In disposal of organic material after treatment, Sharp recommended a cover with activated charcoal. Further, "because of the potentially dangerous nature of the chemicals deposited, great care must be taken in selecting a disposal point where the geological strata and distribution of underground water supplies and watercourses are such that contamination of water supplies or water courses cannot occur" (10).

30. Ned K. Burleson, W. Wesley Eckenfelder Jr., and Joseph F. Malina Jr., "Tertiary Treatment of Secondary Industrial Effluents," in *Proceedings of the 23rd Industrial Waste Conference, May 7, 8 and 9, 1968*, Part 1 (Lafayette, Ind.: Purdue University, 1968), 474–83. See also Cooper and Hager, "Pollution: Water Reclamation with Activated Carbon," where they state: "Activated carbon is effective in removing organic pollutants from waste water and is especially capable of removing biologically resistant (refractory) compounds. Further, carbon retains this effectiveness in adsorbing organics below the concentration where biological treatments are efficient." A useful survey is F. B. DeWalle, E. S. K. Chian, and E. M. Small, "Organic Matter Removal by Powdered Activated Carbon Added to Activated Sludge," *Journal Water Pollution Control Federation* 49 (April 1977): 593–99.

31. PACT later became the registered trademark of ZIMPRO Environmental, Inc., of Rothschild, Wisconsin.

32. O. T. Love Jr., Gordon G. Robeck, James M. Symons, and Ralph W. Buelow, "Experience with Activated Carbon in the U.S.A.," in *Activated Carbon in Water Treatment. Papers and Proceedings of a Water Research Association Conference held at the University of Reading, 3–5 April 1973* (Medmenham, Marlow, Bucks: The Water Research Association, February 1974), 279–95, on 281.

33. Calgon ("Calcium Gone") was a product of the George J. Hagan Co., of Pittsburgh, founded in 1918, and that in 1963 gave its name to the firm after one division, and the Hagan trading name, was sold to Westinghouse. In 1965, Calgon acquired Pittsburgh Activated Carbon, and three years later Calgon was purchased by Merck. Jeffrey L. Sturchio, ed., *Values and Visions: A Merck Century* ([Rahway:] Merck Sharp & Dohme, 1991), 124.

34. Hedden to R. J. Sullivan, copied to C. M. Pike, June 22, 1972, TSME.

35. "This letter indicates that the company wishes a provision in this program giving the company the right to abandon this project if the economics are not acceptable to the

company … With respect to the proposed project schedule, it should be noted that the company has for several years been aware that its wastewater discharge is violating State water quality criteria … It should be noted that the company does not propose to reduce the dissolved solids in the final effluent … The company operates several lagoons for the impoundment of sludges generated in its wastewater treatment plant. Additionally, dumps are used for the disposal of solid and liquid waste generated by this company's operations. These facilities contribute to the pollution of the Raritan River and possibly also to the ground waters in the area." R. Delgado to (recipient illegible), September 13, 1972, TSME.

In March 1973, L. K. Chittenden, American Cyanamid's manager of Public Relations, applied his skills of persuasion in an attempt to get Robert Vincent of the NJDEP to approve the construction of the new lagoon for storage of inert sludge, since "the buildup of solids in [the existing] primary settling basin is at a level where the efficiency of that company's secondary activated sludge treatment plant can be impaired due to (1) loss of detention and equalization time in the primary plant and (2) carryover of primary solids to the secondary plant." Chittenden to R. Vincent, NJDEP, March 23, 1973, TSME. This was followed up with further communications, and agreement over a compromise, following the visit in April of the NJDEP's Joseph M. Mikulka to Bound Brook "for purpose of evaluating the interim measures proposed by Mr. Chittenden of Cyanamid in his letter of March 23, 1973 to Mr. Vincent … The interim measures as stated appear to be satisfactory until the new lined lagoon is ready to be used. However, the interim lagoon when abandoned will contain solids accumulated over the period 1966–1970 as well as over this proposed interim period. Cyanamid does not plan to remove these solids at any time in the future. The lagoon is supplied with a supernatant overflow line, but if this line were inoperable, the content of the lagoon would be subject to overflow from excessive rain, etc. In addition, Cyanamid's lagoons have been subject to leaching in the past. Therefore, it appears that a decision will have to be made concerning the advisability of allowing Cyanamid to leave these accumulated solids in the lagoon after it is abandoned." Memorandum from Mikulka regarding American Cyanamid–Bridgewater Township (recipient illegible), April 9, 1973, TSME.

36. "The New Jersey Institute of Chemists. A Division of the American Institute of Chemists. Annual Plant Tour, Dinner, and Business Meeting, Tuesday, May 8, 1973."
37. The Toms River factory was Ocean County's "largest single private employer with approximately 1,340 men and women on the payroll." An Ocean pipeline, or Main Force, was opened in 1966, and carried liquid waste to the Atlantic. Toms River had also confronted the New Jersey authorities over surface water and well contamination. Its waste treatment system history, apart from the pipeline, had many similarities with Bound Brook. Thus Isaiah Von opines: "The Toms River plant [and] the Calco plant were located on small rivers. They kept expanding despite this until they finally ran into severe problems. DuPont on the other hand had (and has) a huge fine chemicals plant at Deepwater, N.J. which is located on the Delaware River where it is about a half mile wide and 30–40 feet deep. They

never had the kinds of problems that plagued Calco and Toms River. I never understood why the Swiss selected Toms River as a site. Transportation access was not good and no dyestuff markets were close. The only plus was a supply of good labor."

38. From transcript of the stipulation and consent judgment, October 12, 1973.
39. Arthur Brook Crossan III, "The Raritan River 1972: A Study of the Effect of the American Cyanamid Company on the River Ecosystem." (Ph.D. diss., Rutgers State University of New Jersey, New Brunswick, 1974.)
40. Ibid., 12.
41. Ibid., 29.
42. Ibid., 52.
43. Ibid., 73.
44. Ibid., 86.
45. Ibid., 162, 163.
46. Ibid., 232, 233, 234. The thesis also drew attention to dangers posed by heavy metals, particularly copper and zinc, present in the effluent (235).
47. "The Environment: 1973 Progress Report," *Cyanamid News,* August 1973. Reprinted separately, introduced by Clifford D. Siverd, chairman and chief executive officer, American Cyanamid Company. At this time, James Affleck was president, American Cyanamid Company, Ben Loper, president, Organic Chemicals Division, and Richard Phelps, manager of manufacturing, Dyes, Textile Chemicals, and Chemical Intermediates.
48. Reed to Hamilton, July 3, 1974, TSME.
49. "The Bound Brook Plant and Effluent Treatment Facilities. February 1975. American Cyanamid Company. Bound Brook Plant." Prospectus, with introduction by B. H. Loper, president, Organic Chemicals Division, to the Executive Committee, February 21, 1975, 4. The attachments include letters of endorsement from other divisions, dated February and March 1975. The 1973 consent order required the establishment of a monitoring and control program in order to ensure compliance. Some wastes, particularly paper and wood, were incinerated in a "tepee" incinerator between 1957 and 1971. The ash was disposed of by on-site landfill. This practice was declared unsatisfactory when judged by state sanitary and air pollution regulations; American Cyanamid arranged for disposal at two commercial landfills. Tests were undertaken on effluent from the proposed new Tobias acid process in order to establish a flow rate that would not be toxic to the microorganisms used in secondary treatment. The process was a principal contributor to the loads placed on the primary and secondary treatment systems.
50. Transcript of hearing, "Docket No. C-2883-71; State of New Jersey, Department of Environmental Protection v. American Cyanamid: In the Superior Court of New Jersey. September 30, 1975."
51. Affidavit of Ben H. Loper, accompanying motion for extension of time, May 13, 1975. Ibid.
52. Affidavits of Clifford W. Bowers and Edward J. Volke, accompanying motion for extension of time, May 13, 1975; Affidavit of Stuart S. Speter, May 15, 1975. Ibid.
53. Affidavit of Steven P. Lubow, NJDEP, May 21, 1975. Ibid.

54. "My analysis of defendant's continuing discharge indicates that same is one of the most significant continuing environmental hazards and should be abated at the earliest possible date. 5: The discharge from defendant's facility has been and continues to be in violation of New Jersey water quality standards as set forth in the New Jersey Administrative Code. 6: The date to which defendant seeks to have the project schedule extended not only poses a continuing environmental hazard, but is also eight months beyond the federal statutorily-mandated date for compliance with water quality standards ... and is therefore outside and beyond any date which the Department or the United States Environmental Protection Agency may permit. 7: I have reviewed the affidavits submitted by defendant in support of this motion. None of said affidavits sets forth any facts supporting defendant's claim that delays in achieving the agreed schedule of completion were caused by factors 'beyond its reasonable control.' In fact, defendant has never demonstrated to the Department that any such events were beyond its control. 8: It is my opinion and that of the Department that any delay in the project schedules has been within the control of defendant. Plaintiff has never consented to any such delay." From affidavit of Jeffrey Zelickson, NJDEP, May 21, 1975. Ibid.
55. From transcript of hearing, September 30, 1975.

CHAPTER FOURTEEN

1. American Cyanamid was warned that failure to comply with either the consent judgment or the conditions of the NPDES permit "can cause litigation which might result in combined Federal-State penalties up to $53,000 per day."
2. "The Bound Brook Plant and Effluent Treatment Facilities. February 1975. American Cyanamid Company. Bound Brook Plant." Prospectus with introduction by B. H. Loper, president, Organic Chemicals Division, to the Executive Committee, February 21, 1975, and attachments, numbered consecutively (hereafter Loper.)
3. Ibid., 10.
4. Ibid., 11, 12.
5. Ibid. After allowing for the reduction in dye manufacture, the projected share of Bound Brook's TOC load for 1974 was, for intermediates, 17.2 percent, dyes, 8.1 percent, rubber chemicals, 32.5 percent, pigments, 5.7 percent, and pharmaceuticals (Agricultural and Lederle Divisions), 36.5 percent.
6. Ibid., 14, 15.
7. "Sludge Dewatering, Incineration & Advanced Waste Water Treatment Facilities, Bound Brook, New Jersey. Order-of-Magnitude Estimate, OC-1124," to B. H. Loper. Ibid., 22.
8. J. Dlouhy to Loper, February 27, 1975. Ibid., 31.
9. C. E. Austin to Loper, March 4, 1975. Ibid., 32.
10. "Activated Carbon Put to the Test. Lack of Data Posed Problems for Designers of Cyanamid's Huge New Tertiary Waste Treatment Plant in Bound Brook, N.J.," *Chemical Week*, September 29, 1976, 31.

11. For activated-carbon treatment of dye-manufacture waste, as employed at Bound Brook, Toms River, and the DuPont Chambers Works, see, Abraham Reife, "Dyes, Environmental Chemistry," *Kirk-Othmer Encyclopedia of Chemical Technology* (New York: Wiley, 1993) 4th ed., vol. 8, 753–83, particularly 762-3; and Abraham Reife, Don Betowski, and Harold S. Freeman, "Dyes and Pigments, Environmental Chemistry," in *Encyclopedia of Environmental Analysis and Remediation,* ed. Robert A. Myers (New York: Wiley, 1998), 1442–65. See also Abraham Reife and Harold S. Freeman, eds., *Environmental Chemistry of Dyes and Pigments* (New York: Wiley, 1995). Warners also intended to adopt treatment with activated carbon, relying on Bound Brook for regeneration. DuPont studies on the PACT process at its Chambers Works indicated that addition of powdered activated carbon to activated sludge was preferable to the use of columns of activated carbon. See D. G. Hutton, "DuPont PACT Process: Performance and Results from the Chambers Works" (E.I. du Pont de Nemours & Co., Inc., 1979). The use of powdered activated carbon was investigated by the EPA at its Test and Evaluation Facility in Cincinnati from July 1981 to January 1983. See Glenn M. Shaul, Michael W. Barnett, and Kenneth A. Dostal, "Treatment of Dye and Pigment Processing Wastewater by Activated Sludge," in *Proceedings of the 37th Industrial Waste Conference, 1981, Purdue University* (Ann Arbor, Mich.: Ann Arbor Science Publishers, 1982), 677–89. This group, with Timothy W. Neiheisel, presented further results in the paper "Activated Sludge with Powdered Activated Carbon Treatment of a Dyes and Pigments Processing Wastewater," at the 38th Purdue Industrial Waste Conference (1983).
12. "Docket No. C–2883–71; State of New Jersey, Department of Environmental Protection v. American Cyanamid; In the Superior Court of New Jersey, Chancery Division, Somerset County–Supplemental Order. July 31, 1980." This specified limits for color, dissolved solids, and toxicity. In 1978, the NJDEP began actions against American Cyanamid in the same court over groundwater studies, as discussed in chapter 15.
13. Anton C. Marek Jr. and Michael A. Pikulin, "Start-up and Operation of a 20-mgd Granular Activated Carbon Treatment Facility," in *Proceedings of the 33rd Industrial Waste Conference, 1978, Purdue University* (Ann Arbor, Mich.: Ann Arbor Science Publishers, 1979), 105–12. The authors noted that "regeneration performance has proved difficult to control and optimize because of the size of the furnace" (108). Pikulin had received the bachelor's degree, majoring in chemical engineering, from the University of Cincinnati. At Cyanamid he also worked on process plant design for agricultural and pharmaceutical intermediates. In 1993 he received the Thomas A. Edison Patent Award, and in 1997 the American Chemical Society's Hero of Chemistry Award.
14. For regulatory background, and listing of Bound Brook as a National Priorities Site, see *40658–40673 Federal Register* 48, no. 175, Thursday, September 8, 1983. See also *5598–5605 Federal Register* 56, no. 28, Monday, February 11, 1991.
15. To enable compliance with the consent orders, firms of environmental consultants were brought in, mainly O'Brien & Gere Engineers, Inc., and Blasland, Bouck & Lee.

16. "Lower Raritan, South River, Lawrence Brook Management Area," http:/ njwaters.com/wma/09.htm, a project of the New Jersey Public Interest Group Law and Policy Center (accessed December 12, 2001).

CHAPTER FIFTEEN

1. Useful background material is contained in the EPA website "National Priority Site Fact Sheet: American Cyanamid," http://www.epa.gov/region02/superfund/site_sum/0200144c.09.htm (accessed January 18, 2002).
2. W. B. Honachefsky to E. Knape, April 25, 1977, TSME.
3. Geraghty & Miller was founded in the 1950s, and publishes the *Geraghty & Miller Groundwater Bibliography.*
4. Anthony S. Travis, "Instrumentation in Environmental Analysis, 1935–1975," in *From Classical to Modern Chemistry: The Instrumental Revolution*, ed. Peter J. T. Morris (London: Royal Society of Chemistry, 2002), 285–308.
5. R. Bellis to B. H. Loper, October 27, 1977, TSME.
6. "The provisions are for the self defense by the Department ... Evidently it's none of our business what the sludge contains or what they do with it. Provision XXI relates to contamination of groundwater due to ... leakage, sludge storage and manufacturing. We ... [ordered] them [Cyanamid] to make a study to determine the extent of groundwater pollution due to these activities, since we think pollution is involved and feel that this is appropriate." Request for Administrative Hearing, December 1, 1977, TSME.
7. "Amended Notice of Motion for Supplemental Relief to Enforce Litigant's Right in State of N.J., Dept. of Environmental Protection v. American Cyanamid Company. Attaches November 10, 1977 Affidavit of William B. Honachefsky." Submitted to George Y. Schoch, judge of the Superior Court of New Jersey, February 1978.
8. "Please be advised that as the company has been historically one of the most significant dischargers of toxic waste into any stream in the State of New Jersey, the New Jersey Department of Environmental Protection would like to be fully consulted on any settlement proposal." R. Bellis to M. Scolnick, February 16, 1978, TSME.
9. "Docket No. C-2883-71; State of New Jersey, Department of Environmental Protection v. American Cyanamid; In the Superior Court of New Jersey, Chancery Division, Somerset County–Order. April 11, 1978."
10. P. Herzberg to J. Zelickson, April 14, 1978, TSME.
11. W. S. Beggs to Honachefsky, May 1 and 24, 1978, TSME.
12. Edward Stevenson and Richard Dalton replied to Herzberg on June 23, 1978. Following the review of American Cyanamid's May 1978 "Study of Ground Water Conditions at American Cyanamid's Bound Brook, New Jersey Plant," analysis was recommended of all public potable water supply sources that were close to the facility.
13. Herzberg to Knape, July 5, 1978, TSME.

14. Herzberg was also advised that: "It is premature to do the controlled pump tests ... Available information on the abandoned Cyanamid production wells will be supplied by the end of September ... To date we have no analyses of the early wells ... We will define contamination levels within the aquifer by analyzing for five (5) specific indicator chemicals–benzene, toluene, ethylbenzene, xylene and chlorobenzene–based on a suggestion by the State to use indicator chemicals at our June 29, 1978 meeting." Knape to Herzberg, July 27, 1978, TSME.
15. Herzberg to Knape, August 10, 1978, TSME.
16. On February 12, 1980, American Cyanamid provided the EPA with details of materials contained in lagoons. On May 6, the NJDEP reviewed a survey undertaken by McMennamin & Associates (a division of Professional Services, Inc.) which "concluded that certain sections of the sewers have been cracked, fractured, collapsed or showed signs of leakage of the pipe's contents into the groundwater."
17. Engineering consultant O'Brien & Gere was originally a firm of sanitary engineers, founded in 1945 as Holmes, O'Brien & Gere. O'Brien & Gere submitted reports on the Bound Brook facility in 1983, 1995, 1996, and 1997. See also *New Jersey Department of Environmental Protection. 1987. Site Status Report on Hazardous Waste Remediation in New Jersey; Site Specific Information* (New Jersey Department of Environmental Protection, 1987).
18. An important review of the impact of environmental issues in American life is Samuel P. Hays, *A History of Environmental Politics Since 1945* (Pittsburgh: University of Pittsburgh Press, 2000).
19. "Agencies OK Cyanamid Cleanup Effort," *Courier–News*, October 8, 1993.
20. Between 1989 and 1995, Blasland, Bouck & Lee submitted over ten reports dealing with impoundment characterization, soils studies, remediation investigations, feasibility studies, and corrective measures. Lagoons 1 and 2 were subsequently removed from Group III impoundments. According to a late 1990s remedial program the contents of certain Group I and II impoundments were to be solidified and consolidated into impoundment 8. See also Jeffrey J. Winegar, "Revised Site Review and Update. American Cyanamid Company, Bound Brook, Somerset County, New Jersey, CERCLIS No. NJD002173276. Prepared by New Jersey Department of Health, under Cooperative Agreement with the Agency for Toxic Substances and Disease Registry" (1993).
21. Criticisms were blended with condemnations and "revelations," including the accusation that during the 1970s female employees working on lead pigments at Willow Island submitted to sterilization in order to retain their jobs. See "Women Claim Cyanamid Forced Sterilization," *Chemical and Engineering News* 57 (January 8, 1979): 6. American Cyanamid, nevertheless, was not alone in confronting attacks on corporate "fetal protection" strategies. See Christian Warren, *Brush with Death: A Social History of Lead Poisoning* (Baltimore: Johns Hopkins University Press, 2000), 250–52. Damage to crops allegedly from American Cyanamid's Scepter herbicide during 1989, and claims of potential health risks from its genetically modified hormone bovine somatotropin BST (or bovine growth hormone), added to the burden of adverse publicity. For the chemical industry and

its confrontations with alliances of local and national organizations see Barbara L. Allen, *Uneasy Alchemy: Citizens and Experts in Louisiana's Chemical Corridor Disputes* (Cambridge, Mass.: MIT Press, 2003).

22. C. S. Forsyth, "Cyanamid Rep Claims People were Manipulated," *Courier-News*, June 7, 1990. Forsyth also defended the ongoing involvement by American Cyanamid in South Africa: "As an original signatory to the Sullivan Principles, which require equality in the workplace, our commitment to providing quality employment and opportunity is steadfast. And our commitment to helping abolish apartheid and establish race-neutral policies in South Africa has not wavered." Greenpeace demonstrations were later held at Norwalk, Connecticut (Thor's U.S. headquarters); Portland, Maine (on the occasion of American Cyanamid's annual meeting); Wagan, Louisiana; Johannesburg (American Cyanamid's South African headquarters), and Cato Ridge, South Africa (site of the Thor factory). Borden Chemicals and Plastics of Geismar, Louisiana, was among other U.S. firms that shipped mercury to Thor. See "Environmental Justice Case Study: Thor Chemical and Mercury Exposure in Cato-Ridge, South Africa," http://www.umich.edu/~snre492/Jones/thorchem.htm (accessed July 31, 2003).
23. The CEP's "social responsibility" records of major U.S. companies incorporated yet another version of waste history at Bound Brook: In May 1982, "After years of fighting the DEP, Cyanamid enters into an Administrative Consent Order, agreeing to initiate a program to prevent contaminated water from moving off of plant property"; on October 22, 1986, "Cyanamid tells the DEP it cannot complete 12/31/86 cleanup in four of the lagoons"; in March 1987, "DEP fines Cyanamid for failing to comply with agreements." In the opinion of the CEP, American Cyanamid's environmental record was one of the worst in corporate America: "American Cyanamid released an average of 41 pounds of toxic chemicals for every thousand dollars it earned in 1988. The industry average is less than 10 pounds per thousand dollars." See "The Global Battle Against Waste Trade," in *Greenpeace Waste Trade Update* 4, no. 1 (March 22, 1991): 7–8, available on http://www.alternatives.com/library/env/envgtox/hs-wtu.txt (accessed January 18, 2001); "Corporate Relations 101," in *Greenpeace Magazine*, July/August 1990, 5–6, http://www.alternatives.com/library/env/envgmags/gpmag17.txt (accessed January 18, 2001); and "Corporate Environment Record: American Cyanamid," Council on Economic Priorities, 1991, http://www.alternatives.com/library/biz/bizwgen/acycep.txt (accessed January 18, 2001).
24. Jeanette Rundquist, "Bridgewater Demands Greater Role in Cleanup: Mayor Charges DEP Not Protecting Town," *Star-Ledger*, July 19, 1991. See also Laurence Arnold, "State Agency Too Close to Cyanamid, Mayor Says," *Courier-News*, July 19, 1991.
25. Two reports commissioned by CRISIS were prepared by Thomas J. Germine, P.E., "Technical Advisor's Evaluation of Remedial Investigation Studies for American Cyanamid Superfund Site, June 30, 1993," and "American Cyanamid Superfund Site, Bridgewater Township, New Jersey. Technical Advisor's Comments on Group I Impoundments Corrective Measures Study/Feasibility Study Report and the Proposed Remedial Action Plan, July 22, 1993."

26. Public comment had been invited from June 30.
27. "Agencies OK Cyanamid Cleanup Effort," *Courier-News,* October 8, 1993.
28. These included at least six reports by O'Brien & Gere during 1995–97. In the early 1980s, O'Brien & Gere prepared a characterization report for lagoons 1 and 2 (1982), and a lagoon characterization report (1983).
29. Wesley Yang, "No Pollution Found From Cyanamid Site," *Courier-News,* September 24, 1999.
30. "American Cyanamid, New Jersey, EPA ID no. NJD002173276, EPA Region 2, Congressional District 07, Somerset County, Bridgewater Township," fact sheet dated May 2002, http://www.epa.gov/region02/superfund/npl/0200144c.pdf (accessed July 31, 2003).
31. *Pollution News Review* (GeneralCologneRe), January–June 2000, 23, synopsis of a report that originally appeared in the *Bergen Record,* February 22, 2000. Following earlier disputes, the United States insurance industry excluded pollution cover in comprehensive general liability policies.
32. "EPA Region 2, National Priority Fact Sheet, American Cyanamid, August 15, 2000;" EPA website "National Priority Site Fact Sheet: American Cyanamid," http://www.epa.gov/region02/superfund/site_sum/0200144c.09.htm (accessed January 18, 2002); and "American Cyanamid, New Jersey, EPA ID no. NJD002173276, EPA Region 2, Congressional District 07, Somerset County, Bridgewater Township," fact sheet dated May 2002.
33. "Reopening Set for Site Used in Revolution," *New York Times,* April 7, 2002.

CHAPTER SIXTEEN

1. *What We Do at Calco: A Series of Ten Articles Reprinted from the Plainfield* Courier-News *April 1941* (Bound Brook: Calco Chemical Division, American Cyanamid Company, 1941), quoting from first and third articles.
2. Peter J. T. Morris, review of Colin A. Russell, ed., *Chemistry, Society and Environment: A New History of the British Chemical Industry* (Cambridge, U.K.: Royal Society of Chemistry, 2000), in *British Journal for the History of Science* 34 (2001): 350–53, quoting from 352.
3. See, for example: special issue of *Ambix* 49 (March 2002), marking the fortieth anniversary of the publication of Rachel Carson's *Silent Spring;* Susan Groves and Frank Settle, "The Avtex Saga: National Security versus Environmental Protection," *Journal of Chemical Education* 79 (2002): 685–91; and *Proceedings Great Kanawha Valley Chemical Heritage Symposium* (Morgantown, W.Va.: Institute for the History of Technology and Industrial Archaeology, West Virginia University, May 2003).
4. Joanna D. Underwood, "Source Reduction: A Waste Solution," *Chemistry and Industry,* January 3, 1994, 18–21. According to this account, based on surveys by INFORM, Inc.–an environmental monitoring organization founded in 1973–American Cyanamid was by 1992 one of only four U.S. firms with strong corporate leadership in environmental affairs, though it lacked a strong employee-incentive

program. The first comprehensive INFORM report relating to the organic chemicals industry was David J. Sarokin, Warren R. Muir, Catherine G. Miller, and Sebastian R. Sperber, *Cutting Chemical Wastes: What 29 Organic Chemical Plants Are Doing to Reduce Hazardous Wastes,* ed. Perrin Stryker and Patricia Lone (New York: INFORM, 1985).

5. Extending Goldman's argument, chemical firms, as massive technological systems, have been run according to ideological preferences, and not on the basis of science and engineering. Responding to short-term incentives to maximize profits, they neglected capital investment in waste treatment systems that they did not profit from. The outcome was the classic tragedy of the commons, as defined by Garrett Hardin in his "The Tragedy of the Commons," *Science*, 182 (1968): 1243-48. A useful reflection on the impact of industry on the environment is Christine Meisner Rosen, "Industrial Ecology and the Transformation of Corporate Environmental Management: A Business Historian's Perspective," in *Inventing for the Environment*, ed. Arthur Molella and Joyce Bedi (Cambridge, Mass.: MIT Press/ Washington D.C.: Lemelson Center, 2003), 319-38.
6. *What We Do at Calco,* eighth article.

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Entries in *italic* refer to figures, illustrations, and tables.

THIS BOOK explores the rise of the modern U.S. organic chemicals industry through the Bound Brook, New Jersey, facility of the American Cyanamid Company. The site was chosen in 1915 by the Calco Chemical Company for the manufacture of coal-tar intermediates and synthetic dyestuffs previously imported from Europe. After Calco was acquired by American Cyanamid in 1929, the facility diversified into sulfa drugs based on dye intermediates, and novel polymers for the first colored molded plastic goods and ubiquitous melamine laminates. Bound Brook was the international leader in instrumental analysis and color matching of dyes, and contributed to the first phase of the instrumental revolution. It introduced continuous, automated process equipment, with the aim of replacing certain batch processes, though the outcomes were not always as intended. The widespread decline in chemical invention and innovation after 1960 had a considerable impact on the affairs of what had become the Organic Chemicals Division of American Cyanamid. Environmental issues concerning the adjacent Raritan River, a source of water and a sink for waste, had also come to the fore. Pressures from state agencies stimulated innovations in the treatment of liquid waste, including in 1957 the largest biological waste-treatment system in New Jersey, and in 1977 an advanced continuous activated-carbon wastewater treatment plant.

The inclusion of extensive transcripts from interviews and documents connected with the Bound Brook facility provides historians of science, technology, and the environment with valuable resource material.

Cover illustration: *Dyes Made in America, 1915–1940: Calco Chemical Division, American Cyanamid Company* (Bound Brook: American Cyanamid, 1940)

Spine image: Bookplate, Sidney M. Edelstein

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