STATE OF CALIFORNIA
DEPARTMENT OF INDUSTRIAL RELATIONS

EDMUND G. BROWN JR., Governor

OCCUPATIONAL SAFETY AND HEALTH STANDARDS BOARD
1006 FOURTH STREET
SACRAMENTO, CA 95814
(916) 322-3640

PLAINTIFF'S EXHIBIT
UC-5356

SUMMARY

PUBLIC HEARING

April 26, 1979
FRESNO

CALL TO ORDER

Chairman Gerald P. O'Hara called the Public Hearing of the Occupational Safety and Health Standards Board to order at 10:04 a.m. in Room 1036 of the California State Building at 2550 Mariposa Street, Fresno, California on April 26, 1979.

INTRODUCTIONS

Board Members Present	Gerald P. O'Hara, Chairman Edward Ashton Dr. O. Bruce Dickerson William Donnelly Margaret O'Grady Raymond Rodriguez
Board Members Absent	None.
Board's Staff Present	R. T. Rinaldi, Executive Officer Dr. Clinton Vanneman, Senior Industrial Hygiene Engineer John L. Bobis, Principal Safety Engineer Betty Taylor, Industrial Hygienist Mark Ashcraft, Staff Services Analyst GeorgAnn Duarte, Board Secretary
Division of Occupational Safety and Health Administration's	Dr. Fred Ottoboni William Steffan
Others Present	Al Libra, California Manufacturers' Association Jerome F. Cole, Lead Industries Association, Inc. Rudy Florez, UAW Local Union No. 1797 Mark Rickman, Vernitron Piezo Electric Michael J. Connolly, General Motors Corporation Philip K. Edholm, General Motors Corporation J. Wilson, General Motors Corporation E. Wilson Green, E. I. DuPont Company T. O'Donnell, General Motors Corporation Tom Richardson, California Farm Bureau W. M. Pallies, ESB, Inc. M. Sellers, Estee Battery Mike Shaw, Gould, Inc.

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OTHERS PRESENT (continued)

Frank Limon, Gould, Inc.
Keith E. Cooper, Trojan Battery Company
Michael Preston,ESB, Inc.
John Walovich, Prestolite Battery
R. V. Walle, Prestolite
B. B. Pusey, U. S. Steel
G. Sticksel, U. S. Steel
Peter Angelides, Federated Metals Corporation
Roy C. Wahl, Federated Metals Corporation
Lorence L. Timm, Attorney At Law, Hanford
Bill Bristol, CAL/OSHA, San Francisco
Jim Guenther, Federal OSHA, Region IX
Dr. Ira H. Monosson, CAL/OSHA, Los Angeles
Harry Stewart, Prestolite Battery
Richard P. Giaoomazzi, Bethlehem Steel Corporation
R. D. Peterson, R. D. Peterson Associates
R. H. Nason, Daelco, Inc.
R. A. Robinson, Daelco, Inc.
Art D. Gregorio, Plasterers' Local Union No. 2
Ed Maher, Pacific Telephone Company
Ted Saleeda, Plasterers' Local Union No. 489
Charles Ray, Western Plastering
Don Bonusman, EDO Western
Virginia Lew, Department of Industrial Relations
John F. Lewell, California Chamber of Commerce
Charles Manfred, Appeals Board
Bert Davis, Del Monte Corporation
Felix Lollar, Management Safety Consultant
Earl Taylor, E. I. DuPont
David F. Gilbert, E. I. DuPont
John F. Dickey, E. I. DuPont
Ben Hoiland, Ben Hoiland Crane Testing
Arthur Muellett, Sacramento
V. Stefan, V. F. Stefan, Inc.
J. Forrester, Pacific Gas & Electric Company
Anne Bell, CAL/OSHA REPORTER
E. Story, Asbestos Workers Local Union No. 16
Monte Manwill, Asbestos Workers Local Union No. 16
John T. Banister, Associated Roofing Contractors
R. D. Klein, Riverside Cement
Ken Merrigon, Riverside Cement
Richard Hart, B.F. Goodrich
Cliff Erickson, CAL/OSHA, San Francisco
Mike Ota, CAL/OSHA
J. M. Hay, Flintkote Company
John L. Myers, Union Carbide Corporation
Harry Rhodes, Union Carbide Corporation
Zoltan Saary, Chevron Research Company
Jack Brantley, Communications Workers of America
Paul H. Beemer, W. W. Henry Company
Hal Adelman, Southern California Edison Company
Herb Long, Southern California Edison Company
Lloyd Holliday, General Telephone Company
Howard R. Kelly, Gulton Industries

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OTHERS PRESENT (continued)

Dave Crandon, McKinsey & Company
Rick Greenthal, McKinsey & Company
David Kandel, Kaiser Steel Corporation
Thomas P. Feit, W. R. Grace & Company
Don L. Hedges, Norris Industries

CHAIRMAN'S OPENING REMARKS

Mr. O'Hara indicated that the Standards Board is a part-time, independent Board mandated by the Legislature to hold public hearings on proposed standards which will provide such freedom from danger as the nature of the employment reasonably permits. The Board's policy is to adopt standards which are enforceable, reasonable, understandable and contribute to the safety and health of California employees.

The Chairman called attention to the agenda indicating there are building standards to be considered at the Public Hearing. He stated the Board's intent is to promulgate into Title 24 those safety regulations that also building regulations. He stated the purpose for doing so is to eliminate conflict, duplication and overlap in building standards and Title 8 standards.

PROPOSED SAFETY STANDARDS

1. GISO, Sections 3319(a), 4309(d) and (f), 4924, 5001(d), 5021(c), 5022(d), 5025.

Page 1, Section 3319(a) — No Comments.

Page 2, Section 4309(d) — Mr. Bobis of the Board's Staff indicated that the proposed revisions to Subsections (a) and (f) were adopted by the Board last month. The only revisions for hearing concern Subsection (d). There were no comments.

Page 3, 4924(a) — Mr. Bobis recommended that the reference to "Division of Industrial Safety" be corrected to reflect the new agency's name of "Division of Occupational Safety and Health Administration". The Board concurred.

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PROPOSED SAFETY STANDARDS (continued)

1. GISO, Sections 3319(a), etc. (continued)

Page 4, 5021(c) "Note"

Mr. Ben Hoiland of Hoiland Crane Testing indicated that, in his opinion, backhoes and casting-type work should not be exempted. He recommended that the "Note" read: ". . .backhoes or breaking balls, when not used for lifting service. . ."

Mr. Rodriguez, Board Member, recommended that "casting-type work" be defined in the Orders, irregardless of whether or not it is a common term in the construction industry. Mr. Bobis agreed that it could be defined to clarify the "note".

There was considerable discussion concerning the provisions of Mr. Hoiland's remarks and their applicability to the wording in note.

Mr. Bobis stated that the "note" was prompted as a result of an Appeals Board Decision where backhoes were cited for not being certified, which was not the intent of the regulations. He stated the intent of the regulations was to include only that equipment which is used to lift, and backhoes are not used in that case.

Mr. Rinaldi indicated that the Board's staff would review the "Note". Mr. O'Hara concurred

Page 7, Plate V, Title

Mr. Bobis recommended that the reference to "Division of Industrial Safety" be corrected to reflect the agency's new name.

2. Title 8, Construction Orders & Title 24, Part 2, Basic Bldg. Reg. Section 1528(c) and B1750., "Spraying of Asbestos"

Dr. Vanneman indicated that these proposed revisions were based on the mandate of Senate Bill 1591, enacted in 1978, in which the Board was authorized to adopt standards pertaining to exemptions of the Health and Safety Code Section 25910 concerning the prohibition of spraying of asbestos in or upon buildings or structures during their construction, alteration or repair. He stated that on November 8, 1978, the Board

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PROPOSED SAFETY STANDARDS (continued)

2. Sections 1528(c) and B1750 (continued)

conducted a Public Hearing in which testimony was received concerning the provisions of Senate Bill 1591; and that Dr. Fred Ottoboni, consultant to the Board at that time, analyzed the results of that testimony and proposed these revisions accordingly. The Board's staff concurs with the proposal.

Page 1, (c)(2)

Mr. Donnelly suggested that perhaps the exemption should include a concentration limit.

Dr. Ottoboni stated that, in his opinion, it would not be necessary; however, if abuses would occur then it would be necessary.

Page 1, (c)(4)

Mr. Bill Steffan of DOSHA stated that in his opinion, 1/4 of 1 percent cannot be adequately measured and recommended that the level be changed to 1 percent, which would read: "Substances containing less than 1 percent. .

Dr. Ottoboni stated that he recognizes Mr. Steffan's suggestions that below 1 percent asbestos essentially becomes invisible in a bulk sample; however, the trend toward improved analytical techniques would allow the measuring of 1/4 of 1 percent; and that, in his opinion, the law (SB 1591) specifies 1/4 of 1 percent.

Page 1 and 2 (c)(2) and (3)

Mr. John Myers of Union Carbide recommended that the proposed wording for exceptions (c)(2) & (c) be replaced with the language contained in part (c)(1) of Senate Bill 1591, which reads: "Exterior and interior coatings and laminating resins containing escapulated asbestos fibers found within the finished product from manufacture through application and cold process asphalt roof coatings.".

He stated the language in SB 1591 would incorporate (c)(2)and (3). He also indicated the same corrections be made on page 2 relating to the building standard Section B1750.

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PROPOSED SAFETY STANDARDS (continued)

2. Section 1528(c) and B1750 "Spraying of Asbestos" (continued)	Mr. Myers urgently requested the Board to take immediate action on this proposal due to the time limitation of July 1, 1979.
MOTION	A motion was made by Mr. Ray Rodriguez, seconded by Mrs. Margaret O'Grady, to amend 1528(c)(2) and (3); and Section B1750 (c)(2) and (3) to reflect the wording of Senate Bill 1591.
ROLL CALL VOTE	A roll call vote was taken and all Board Members voted "aye". Motion carried unanimously.
	At this time, Mr. Rinaldi requested the Board to defer action on this subject until the Board's scheduled Business Meeting. Mr. O'Hara concurred.
3. General Industry Safety Order Section 5208, Asbestos	Dr. Vanneman indicated that the proposed changes to page 1 were prompted by SB 1591; and the changes to the monitoring and medical surveillance provisions were prompted by a letter from Federal OSHA requesting that such changes be made.
Page 1, (c)(3)and (c)(4)	Mr. John Myers of Union Carbide recommended that the phrase "or otherwise handled" be added after the term "ventilated", in Subsection (c)(3).
	He also requested that the same changes be incorporated into Subsection (c)(4), Exceptions" as indicated by the Board's action in Section 1528 to use the Senate Bill language.
	Mr. Vanneman and Dr. Ottoboni both agreed that there would be no problem in adding Mr. Myers' suggested phrase.

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PROPOSED SAFETY STANDARDS (continued)

3. GISO, Section 5208 (continued)

Page 2, (c)(5)

Mr. Myers recommended that this subsection be changed to reflect the Federal wording. He indicated that the proposal as written deletes the "disposal" provisions as contained in the current Federal language. Dr. Vanneman stated he had no objections to using the Federal language in lieu of the present wording.

Page 4, (g)(1)

Mr. Bill Steffan indicated that the Division recommends to retain the original language in existing Subsection (g); and in (g)(1)(A) lower the level from 1 fiber to 1/10 of a fiber. He also requested that (g)(1)(C) be changed to 1/10 of a fiber and to remove the ceiling concentration designation.

Levels of Monitoring Issue

Mr. C. H. Long, Southern California Edison Company, objected to Mr. Steffan's recommendation to reduce from 1 fiber to 1/10 of a fiber. Mr. Long indicated that should the Board consider Mr. Steffan's proposal, the matter should be rescheduled for another public hearing since, in his opinion, this would be substantial change.

Mr. Harry Rhodes of Union Carbide disagreed with Mr. Steffan's proposal to lower the monitoring at 1/10 of a percent. He stated that, in his opinion, there is no absolute standard which could calibrate a measurement. He had no objections in using the Federal language but recommended to define administratively what exposure is.

Mr. Don Hedges of Norris Industries also agreed that a definition should be incorporated for the term "exposure" to clarify the intent.

There was considerable testimony regarding the feasibility of different action levels for monitoring; however, Mr. John Myers of Union Carbide requested an exemption of brake shops due to economic impact on employers, tremendous enforcement difficulties for compliance engineers; and would require massive technical resources in an area of low exposure and low risks.

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SUMMARY OF THE PUBLIC HEARING

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PROPOSED SAFETY STANDARDS (continued)

3. GISO, Section 5208 (continued)

Page 4

At this time, Mr. O'Hara recommended that perhaps it would be appropriate to take Board action since the testimony taken at the hearing had the support both from management and labor to change the action level to .5

MOTION TO CHANGE THE ACTION LEVEL TO .5

A motion was made by Dr. Dickerson, seconded by Mr. Ray Rodriguez, to adopt the action level of .5 fibers per cc longer than 5 microns.

ROLL CALL VOTE

All Board Members voted "aye". Motion carried unanimously.

Dr. Fred Ottoboni requested clarification on the motion as to whether or not the motion intended to mean .5 time-weighted average. Dr. Dickerson replied that it was meant to be the "twa" factor.

Pages 5 through 8

No comments.

Page 9, (j)(3), Annual Examinations

Dr. Ira Monosson, DOSHSA, requested that additional provisions be incorporated to clarify that any examination should be provided for employees exposed above .5 fibers and for employees who are no longer occupationally exposed to asbestos at or above .5 and work with the same employer provided that:

1) Such employee had a total occupational exposure of 5 or more years; or

2) A total of at least 5 years elapsed since initial occupational exposure and that total exposure time exceeded 30 working days.

The Board Chairman indicated that, in his opinion, the proposal of Dr. Monosson would be more appropriate to consider at a future date.

Mr. Rinaldi stated that if the Board elects to incorporate the proposals submitted by Drs. Ottoboni and Monosson, the Board, in his opinion, should reschedule the proposal

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SUMMARY OF THE
PUBLIC HEARING

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PROPOSED SAFETY STANDARDS (continued)

3. GISO, Section 5208 (continued)

Page 9, Annual Exams

for a future public hearing since there were substantive changes recommended to the standar He also indicated that the Board's staff would work with the Division on the proposals. Mr. O'Hara concurred.

Page 10, Access to Medical Records Issue

Mr. Dave Kandell, Kaiser Steel Corporation, objected to the wording concerning the availability of the employee's personal records to be reviewed by the different agencies without the employee's consent. He proposed that the language stipulate the type of data that could be made available and recommended that the phrase "upon the request of the employee or the former employee" be added to clarify the proposal.

He also requested that clarification of the last sentence be made which states, in part, ". . . and any other medical information. . .". In his opinion, what would be "any other information"?

The Board Chairman agreed with the recommendation that the wording should be rewritten to clarify the intent.

Mr. Ashton, Board Member, recommended that the subsection be rewritten to specify that the "employee's name" be deleted on the medical records; however, Dr. Dickerson, Board Member, stated that the Board's staff should review this matter with the Department's Legal Unit, but agreed that a differentiation should be made between occupational and nonoccupational records.

Page 11, (z)(1)(B) Compressed Air Issue in Brake Shops

Dr. Fred Ottoboni objected to the Division's memorandum in which they proposed deletion of the term "compressed air". He stated that in his opinion, the term should not be deleted for the reasons that there are 2 operations in brake shops where employees may receive harmful doses of asbestos; (i.e., the blowing out of brakes with compressed air; and grinding of brake lining). He stated

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PROPOSED SAFETY STANDARDS (continued)

3. GISO, Section 5208 (continued)

that, in his opinion, these operations should be made specific and that deleting the phrase "compressed air" would be detrimental. Mr. O'Hara concurred.

At this time, Mr. O'Hara, Chairman, instructed the Board's staff to review the asbestos standard in view of the issues which were raised by Drs. Ottoboni and Monosson and Art Carter's recent memorandum and the staff to reschedule a future public hearing due to the substantive new testimony on the proposal. At this time, Mr. O'Hara recessed the Public Hearing for one hour.

4. GISO, Section 5209(f)(1), Reporting of Carcinogens

Dr. Vanneman stated these proposals resulted from two appeals court cases in which the employer had neither reported the use of certain substances covered by the Section and had not established a regulated area. The judge ruled that the employer had the need to report only if he established the regulated area. The changes as recommended by the Division are to remove possible misinterpretations in the future.

There were no comments on this proposal; however, Al Libra of California Manufacturers' Association asked if the Board would keep the record open on this proposal for ten days. Mr. O'Hara indicated that is the policy of the Board on all items at Public Hearing.

5. GISO, Section 5216, "Lead" Standard

Mr. O'Hara indicated that the final item on the Board's agenda is the proposed new General Industry Safety Order Section 5216 for the control of occupational exposure to lead. As proposed in the hearing packet, the standard closely parallels, both in content and in language, the corresponding Federal standard which was published in the Federal Register on November 14, 1978.

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PROPOSED SAFETY STANDARDS (continued)

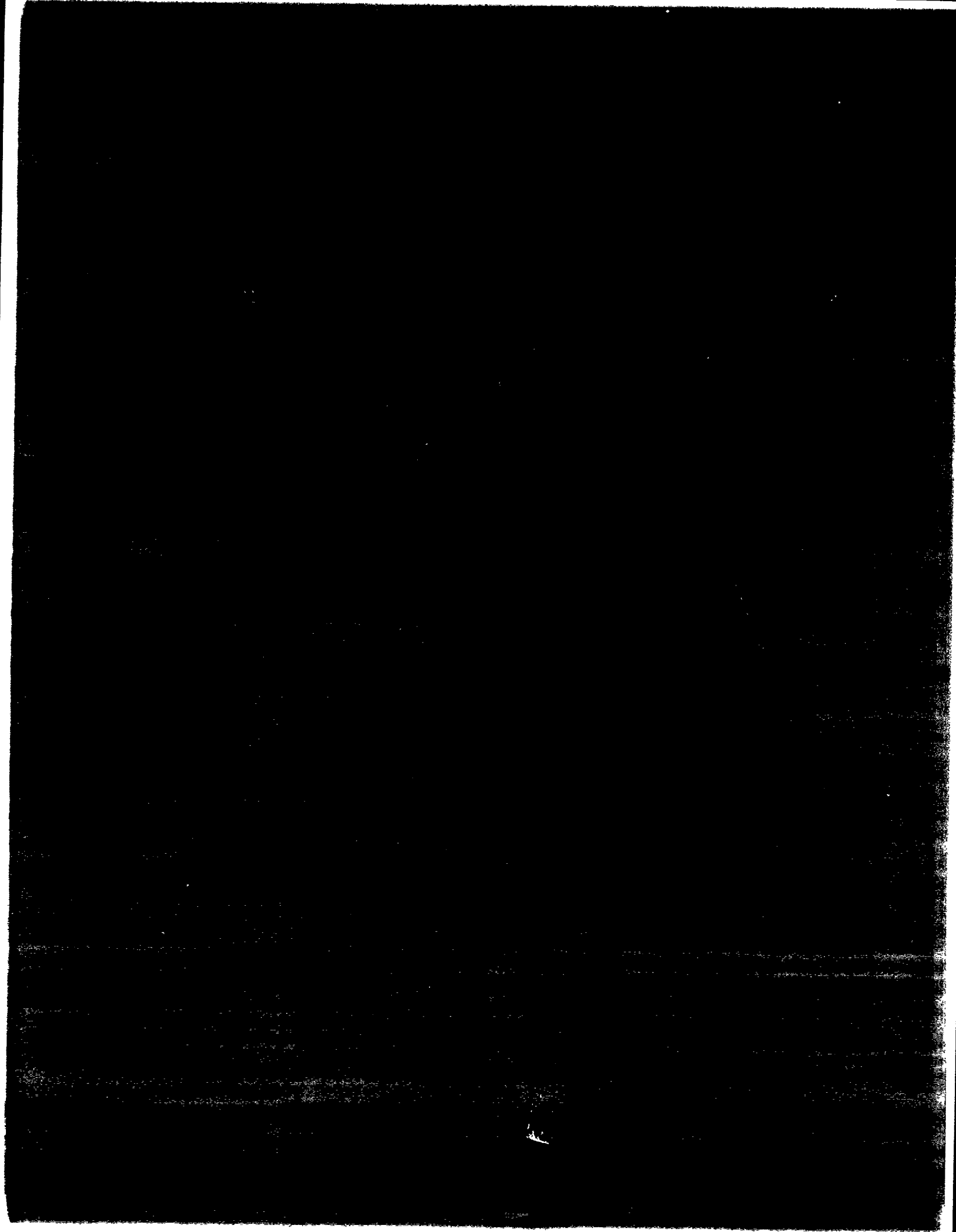
5. GISO, Section 5216, Lead (continued)

Mr. O'Hara's comments (continued) On March 1, 1979, the United States Court of Appeals for the District of Columbia Circuit ordered a partial stay of the Federal "lead standard. This stay will continue pending the Court's consideration late this year of the challenge to the standard. It is the Board's intent to limit testimony on proposed Section 5216 to those portions of the standard which were not stayed by the Appeals Court. If the Court acts to reinstate, or otherwise alters in a substantive manner, portions of the Federal standard, this Board will assess the effect of such corresponding changes to Section 5216 at another Public Hearing.

Mr. O'Hara apologized on behalf of the Board for any inconvenience the public may have experienced because the proposed standard did not reflect the Court Order. However, in order to avoid postponing the hearing of the proposed State lead standard until a later date, it was necessary to finalize the Board's Public Hearing "Notice" prior to the outcome of the Court decision. Under the Board's legislative mandate to adopt an "at least as effective as" State standard within 6 months, the Board cannot always await the outcome of legal challenges to Federal occupational safety or health standards.

As in

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Chapter One
GENESIS (1890-1920)

Ethyl alcohol has been made by fermentation since time immemorial in the making of beer and wine, and the roots of synthetic organic chemistry go back to 1828 when the German chemist Friedrich Woehler synthesized urea from ammonium cyanate. The organic chemical industry, however, began in the mid-1800s in Europe, largely in Germany, based on coal and coal-tar chemicals. Coal-tar chemicals are aromatic in nature, that is they have a makeup that incorporates the benzene ring in their structure. The driving force for much of the early development in organic chemicals was the need for synthetic dyes for the growing textile industry. The demand for explosives also was an important factor. Whole industries grew out of these developments. Germany was a particularly fertile ground for the development of organic chemicals because of its unique working relationships between industry and the universities. Up to that time much if not most industrial development was empirical. A scientific approach, afforded by German universities, provided the means for development of the organic chemical industry that would not have been possible otherwise.

Petroleum refining and petrochemicals, however, are more recent and are largely American developments. Petrochemicals are chemicals derived from petroleum and are different from coal-tar chemicals. They are more properly termed synthetic aliphatic chemicals and generally have a linear or branched structure rather than a ring structure. There is of course no absolute dividing line between the two areas, indeed there is considerable overlap in practice.

Growth of petrochemicals in the United States was based on the ready availability of inexpensive gas and oil and on the growing but largely undefined needs of the automobile industry. Growth was facilitated by the newly emerging discipline of chemical engineering, with its emphasis on definable and continuous processing methods, which were needed to build large plants with economies of scale. Interestingly, many new petrochemical products found their own applications rather than the other way around. Early applications were as solvents for paint and other

things, anti-freeze, intermediates for making low-temperature dynamite, dyes, pharmaceuticals, and so on. Ultimately, whole industries derived from petrochemicals: plastics, packaging, paints, fibers, fertilizers, solvents, synthetic rubber, agricultural chemicals, and a host of others. However, most petrochemicals, with the exception of plastics, are intermediates that the general public never sees and doesn't recognize.

The principal building block in the petrochemical industry is ethylene, an unsaturated aliphatic hydrocarbon molecule that consists of two atoms of carbon and four atoms of hydrogen. It is a member of a family of unsaturated aliphatic chemicals called olefins. Propylene is also a member of this family having three carbon atoms and six hydrogen atoms. Ethylene, which is a gas at atmospheric temperatures and pressure, has been known since 1795. Until the 1920s, what little was manufactured was made by chemically dehydrating ethyl alcohol that had been produced by fermentation. Ethylene was first produced in quantity in the early 1920s by Union Carbide and Carbon Corporation by cracking natural gas liquids. From that time Union Carbide has led the industry in the development and manufacture of ethylene and its derivatives. The next major producer of ethylene was Dow Chemical in 1941. By that time, Union Carbide had built four ethylene (olefins) plants (three in Charleston, West Virginia, and one in Whiting, Indiana) and was in the process of completing a fifth in Texas City, Texas.

Willson Aluminum Company

Union Carbide Corporation owes its existence to a Canadian inventor named Thomas Leopold Willson. Willson, who was born in 1860 to a well-to-do family in Princeton, Ontario, had a consuming interest in electric power, especially in electric arcs and dynamos. He had invented neither, but held numerous patents on their uses and improvements. In the 1880s, electric power was in its infancy, and Willson had promoted the use of electric arcs for street lighting in Hamilton, Ontario. Willson, however, was unsuccessful in his venture, and he set off to try his luck in the United States. He initially worked as an electrical inspector but experimented on the side with an electric arc furnace provided to him by the Eimer and Amend Company, chemical distributors in New York City, the forerunner of Fisher Scientific. Willson was particularly interested in reducing refractory ores—that is, hard to smelt ores—to their base metals in an electric arc furnace, and had secured a patent in



Figure I
Thomas Leopold Willson 1860 - 1915

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in 1890 to the rights to the use of the electric arc for ore smelting. He especially thought that he could make aluminum by smelting bauxite, an aluminum ore, mixed in pitch—a source of carbon—to reduce the ore to the metal. Aluminum held great promise as a new metal. Charles Hall, while still at Oberlin College in Ohio, had developed in 1886 a successful process for electrolytically reducing bauxite to aluminum. Hall's success had set off a craze to find other ways to produce it. Whereas, Hall used electrolysis, Willson proposed and tried to reduce aluminum ore thermally, that is, by high heat, in an electric arc furnace. However, Willson's work in the laboratory was not particularly successful. Small bits of aluminum were produced but there was no flux to permit them to agglomerate. He thought that a larger scale of operation might turn the trick, but for that he needed capital and a source of power.

Spray Plant

Willson was acquainted with George F. Seward, president of the New York Fidelity and Casualty Company, and approached him for help. Seward was interested and brought in Major James Turner Morehead, a North Carolina entrepreneur, who owned a water-powered cotton mill in Spray (now Eden) North Carolina. Morehead had surplus water power available and was looking for ways to put it to good use. He was also interested in making aluminum. As a result, Seward and several others—including Eimer of Eimer and Amend—put up $30,000, and with Willson and Morehead, formed the Willson Aluminum Company. Morehead was president, Seward was vice-president, and Willson was secretary.

Major Morehead's role in the venture was primarily that of fund raiser and entrepreneur. He also, of course, owned the plant site. Morehead was a member of a prominent North Carolina family—his father had been governor of the state—and he was a wounded veteran of the Confederate Army. He also had made a fortune after the Civil War in textiles and flour milling. However, he had gotten overextended building the Cape Fear and Yadkin Valley Railroad and had lost his money in the financial panic of 1888. He was holding on by the skin of his teeth at Spray and hoping to recoup.

Willson and Major Morehead went to work in 1891 at Spray to put together a facility to make aluminum. They hired John Motley Morehead, the son of Major Morehead and a recent graduate of the University of North Carolina, as the plant



Figure II
Major James Turner Morehead 1840 - 1908

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chemist. They also hired a couple of local farm boys, Jesse King and Edgar Price, as operators, plus two laborers. Willson bought a 300-HP water wheel and designed and built a 35-volt, 2000-ampere water-powered alternating current electric generator. He also designed and built an electric arc furnace with a carbon crucible that was 20 inches in diameter and about a foot deep. It had a hollow pencil electrode that was one-and-one-quarter inches in diameter, and which could be moved up or down in the crucible on a screw to follow the mass that was being smelted. The other electrode was the crucible itself. The process was carried on in a batchwise manner.

Operations, or rather experimentation, started in 1892. To make a run, finely ground alumina was mixed with coal tar, the mixture was heated to drive off the volatile matter, and the resultant mass cooled and crushed to form a black powder. An arc would be struck in the furnace and the mixture slowly shoveled in. The pencil electrode would be raised as the mass liquified. When the furnace was full—about 35 to 40 pounds of mixture—the resultant mass would be held in a liquified state for about two hours. The mass was then cooled and removed.

The scaled-up process didn't work any better than it had in the laboratory. Without an effective flux, the small amount of aluminum that was produced remained dispersed in small globules in the furnace charge. Many tests were run without success. To defray expenses, Willson fell back on making aluminum bronze, which consists of about twenty percent aluminum and eighty percent copper. This was done by adding granulated copper to the furnace charge. Willson had earlier patented this process, but the market for aluminum bronze was small at that time and it could not support the operation.

Willson then came up with an idea that it might be possible to reduce alumina in an electric arc with an active metal like calcium. But first they had to make some calcium. So, on May 2, 1892, they set about in an impromptu fashion to make calcium in the electric arc furnace. First, they mixed sixty pounds of slaked lime— calcium hydroxide—which had been purchased to whitewash the walls of the building—with five gallons of coal tar. The mixture was then heated to drive off the volatiles, crushed to powder, and fed to the arc furnace. After two hours, the furnace was tapped and some of the melt ladled into a bucket of water to cool it. Gas and steam erupted immediately and exploded into flame, ignited by the red hot melt. Knowing that calcium reacts with water to produce flammable hydrogen, their initial reaction was that they had made calcium. Willson, who was in Asheville during the experiment, notified his patent lawyer in New York to that effect.



Figure III
John Motley Morehead 1870 - 1965

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The remainder of the melt was allowed to cool and was taken out of the furnace as a brittle, crystalline mass. Again, some of the cooled mass was dumped into water and again it erupted in gaseous bubbles. John Motley Morehead tied an oily rag to the end of a fishing pole, lit it, and swung it over the bubbles. Again the gas ignited, but it burned with a dense black smoke. Morehead was suspicious. He knew that calcium reacting with water would produce hydrogen which burns with a colorless flame. The black smoke was indicative of the presence of carbon in the gas. He took the crystalline material to his laboratory and analyzed it. In several days he had determined that it was, as he called it, the carbide of calcium, or as we know it today, calcium carbide. However, he could not identify what the gas was that was being given off when the calcium carbide was immersed in water. In any event, Willson applied for a patent in August of 1892 for the process for making crystalline calcium carbide. The wonder of it all was that, by chance and on the first try, they had hit upon the necessary conditions and proportions of lime and coal tar to make calcium carbide. (Later, coke was used in place of coal tar.)

Dr. Francis Venable, a chemistry professor at the University of North Carolina—and later president of the University—served as a consultant on the work at Spray. He took some calcium carbide back with him to Chapel Hill for further study. In the fall of 1892, a student assistant, William Rand Kenan, identified the gas given off by the reaction of calcium carbide and water as acetylene. He also observed that acetylene burned with a brilliant white flame, brighter than any other gas flame known, when properly mixed with air.

Calcium carbide and acetylene had been prepared and identified in 1862 by the German chemist, Friedrich Woehler, who had made it in the laboratory by heating a zinc-calcium alloy and charcoal. However, he had not produced crystalline calcium carbide and nothing further had been done since that time. Henri Moissan, a French chemist, had also independently made calcium carbide from lime and charcoal in an electric arc furnace at about the same time that Willson did. Willson was first, however, as corroborated by Professor Venable's work at Chapel Hill and by the dates of Professor Venable's correspondence about the invention with Lord Kelvin in England. It was also confirmed by the German Patent Office, which annulled Moissan's patent claims. Willson's United States Patent No. 541,138 for the manufacture of a new product, crystalline calcium carbide, was issued on June 18, 1895.

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The discovery of processes to make calcium carbide and acetylene were momentous, but not a call for rejoicing. There was no immediate market for either with which to pay the bills. In the summer of 1892, John Motley Morehead, Edgar Price, and one of the laborers were laid off. The operation continued with Willson, Jesse King, and a laborer. Mostly they made aluminum bronzes and calcium carbide. John Motley Morehead was paid in Willson Aluminum Company stock in lieu of salary (apparently, he had continued to live with his father in Spray and thus had his room and board.) Morehead got a job first with a bank in New York, then with Westinghouse in Pittsburgh, and then served as a consultant. Price got a job with a railroad in West Virginia. Both would be gone for several years, but both would be back.

In the spring of 1893 the country had another financial crisis, and the Willson Aluminum Company was faced with failure. Major Morehead was sold out by his creditors and was left owing $200,000. However, he was allowed to continue the smelting operation at Spray. He sought to sell the calcium carbide process and its patents in the United States, in England, and in Germany, but had no takers —not even for as little as $5000. Willson went to New York and tried to sell calcium carbide. Finally, in January of 1894, Willson sold a ton of calcium carbide to Eimer and Amend, the chemical supply house that had provided some of the original backing for the venture at Spray. Eimer and Amend also provided support and facilities for Willson to develop chemical uses for acetylene, such as the manufacture of chloroform, aldehydes, and calcium cyanide. Unaware, however, of the explosive nature of compressed acetylene, they suffered an explosion and fire that destroyed their laboratory, which ended their experiments. Nonetheless, Willson applied for a patent in 1894 for the production of acetylene derivatives and for the use of acetylene as an illuminating gas.

In spite of his financial difficulties, Major Morehead was able to borrow more money and keep the Spray facilities going. He had a talent for being able to borrow money without collateral. He hired a Dutch chemist, Dr. Guillaume de Chalmot, in 1894 to improve the calcium carbide process and operations. Whereas most of the earlier work had been done on an empirical basis, Dr. de Chalmot brought a scientific approach to the process. He successfully improved the calcium carbide process and operations and also developed processes to make ferroalloys— ferrochrome and ferrosilicon—and silicon in the arc furnace. Indeed, de Chalmot, who died in 1899 at the age of 29, set the stage for commercial

entry into the manufacture of both calcium carbide and ferroalloys. His untimely death cut short a promising and significant career.

The Spray plant was rebuilt and enlarged in 1894. It had two arc furnaces, and had become the first commercial calcium carbide plant. Major Morehead and Willson continued to promote their product. Through Edward N. Dickerson, a patent lawyer, they met George O. Knapp of the Peoples Gas Light and Coke Company of Chicago, and they interested him in using acetylene to enhance the luminosity of town gas (water gas), which was a primary source of home lighting at the time. As a result, in late 1894, Knapp and Charles F. Dieterich—also of Peoples Gas Light and Coke Company—bought the Willson Aluminum Company's United States rights for manufacturing calcium carbide for illuminating purposes. They formed the Electro Gas Company to exploit the opportunity, which they did by selling franchises for district rights for manufacturing calcium carbide. One of the franchises was acquired by Major Morehead. All of the other rights relating to calcium carbide and the electric arc furnace, including chemical derivatives and metallurgical processes, were retained by Willson Aluminum. Willson personally retained all the rights for Canada.

The use of acetylene for lighting began to take off in 1895. The catalyst for the increased usage was the development by Dickerson, the lawyer, of a safe and effective means of compressing and storing acetylene and of practical burners for lighting purposes. The demand was great and acetylene lights were soon to be found on farms, on city streets, on bicycles, on railroads, and in mines.

Holcomb Rock and Glen Ferris Plants

The Spray plant burned in 1896 and was not rebuilt. Instead, Major Morehead built a new, 12-tons-per-day calcium carbide plant at Holcomb Rock on the James River near Lynchburg in Virginia. It was powered by a hydroelectric system that utilized an old dam that had been built as part of the Kanawha and James River Canal, which was now defunct. Guillaume de Chalmot was the plant manager, and under de Chalmot the plant thrived. He optimized a dozen or so variables in the process ranging from the type of lime used to appropriate voltages and amperages for the arc furnaces to the best size for calcium carbide ingots. He also continued to make and experiment with ferroalloys.

In 1897, Major Morehead built a second hydroelectric smelting plant at the ad of navigation at the falls at Glen Ferris on the Kanawha River in West Vir- a. However, this plant was dedicated solely to the manufacture of ferroalloys. plant started up just in time to provide large amounts of ferrochrome to the Navy for armor plating ships during the Spanish-American War. The first intendent of this plant was Thomas R. Ragland, Sr., who also had hired in at ay.

lcium Carbide Franchises

Electro Gas Company sold eight franchises for the manufacture of calcium bide—five in the United States and three in Europe. Most of the franchisees led, and the franchising business got a bad name. The only successful franchi- es were Major Morehead with his plant at Holcomb Rock, the Lake Superior arbide Company (formed by George O. Knapp of the Peoples Gas Light and oke Company) which had a plant at Sault Sainte Marie in Michigan, and the etylene Light Heat and Power Company of Philadelphia, which had a plant at agara Falls in New York. The plant at Niagara Falls was viable, in part, because y had hired Edgar F. Price, who had been at Spray, as Superintendent. They also hired Jesse King and William Rand Kenan, and John Motley Morehead was ned as a consultant.

A major breakthrough in calcium carbide manufacturing was made at the t Sainte Marie plant. William S. Horry, an engineer, invented a rotary furnace produced calcium carbide on a continuous basis and reduced the cost of manu- ure considerably. The new furnace needed less manpower to operate, but more ortantly, it reduced the cost of electric power. Now power could be contracted at a level needed to operate continuously, rather than at the higher level needed support the old on-off batch process. A facsimile copy of a letter from Horry to orge O. Knapp dated January 26, 1897 regarding work on a furnace is shown in ure VI. This is the first known Research and Development report in Union bide's history.



Figure IV
Former Willson Aluminum Company Plant
at Holcomb Rock, Virginia in 1929

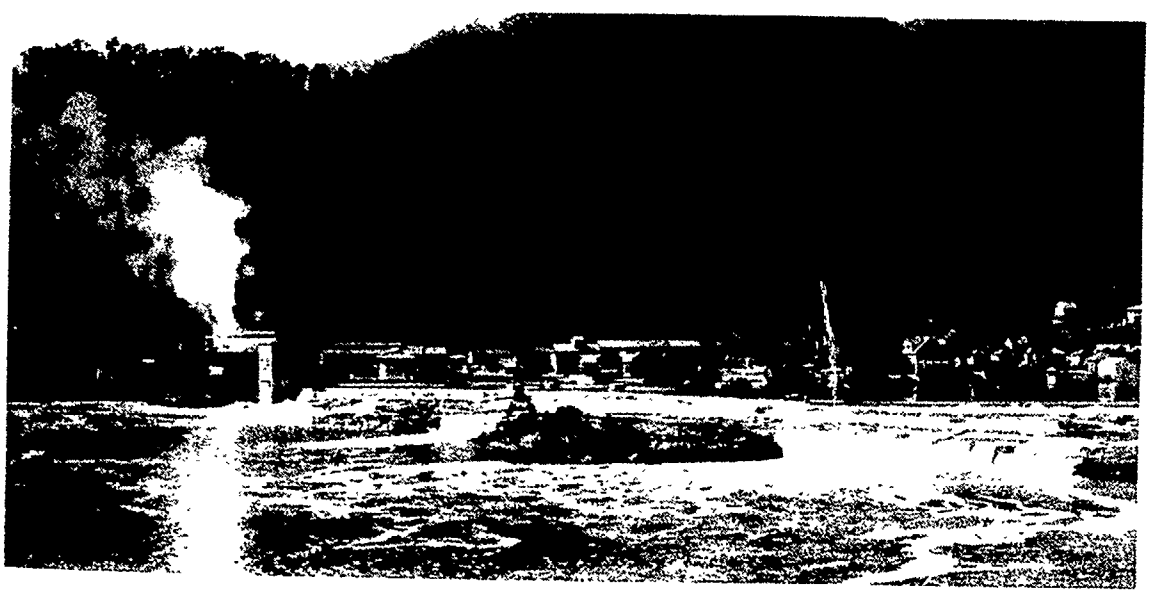


Figure V
Electro Metallurgical Plant
at Glen Ferris, West Virginia in 1929

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on Carbide Company

Peoples Gas Light and Coke believed that there was more opportunity here they had previously recognized. Therefore, they formed a new company in to take over the Electro Gas Company and buy out the surviving franchi- the Lake Superior Carbide Company with its plant at Sault Sainte Marie, cetylene Light Heat and Power Company with its plant at Niagara Falls, and Willson Aluminum Company, with its plant at Holcomb Rock.

They called the new company Union Carbide Company. The incorporators led George O. Knapp and Cornelius Kingsley Garrison Billings, also of es Gas Light and Coke Company. Knapp later would be the first president of n Carbide and Carbon Corporation. Billings, who was one of the richest men nerica, later would be a chairman of Union Carbide and Carbon Corporation.

tro Metallurgical Company

The capacities of the plants at Sault Sainte Marie and Niagara Falls were expanded. Edgar F. Price, the superintendent of the Niagara Falls plant, had s capacity and experimented with ferrosmelting, as de Chalmot had done at and Holcomb Rock. He developed some patents and some facility in deal- th ferrosilicon operations and then sold an initially reluctant board at Union e Company on getting into the metallurgical business. The first thing that d, in 1906, was to form a subsidiary, the Electro Metallurgical Company, y out Major Morehead and the remainder of the Willson Aluminum Com- The facility that was involved was the plant at Glen Ferris, West Virginia. that time forward, Union Carbide was in the ferroalloy business. In the pro- Major Morehead got well financially. John Motley Morehead also benefitted ntially. He had received Willson Aluminum Stock in lieu of salary and had a stake in Union Carbide Company. Union Carbide also bought out Thomas on's carbide interests in Canada in 1914. The Willson Aluminum Company, never made any aluminum, was eventually dissolved (in 1916).

In order to secure the services of Dr. Frederick M. Becket, The Electro llurgical Company purchased the Niagara Research Laboratories. Dr. thad developed low-carbon ferrosilicon as an agent to replace carbon as the ng agent in the manufacture of modern alloy steels. Dr. Becket became the

Jan'y 26 7

Geo O Knapp Esq

Dear Sir

The carbons arrived and the furnaces are running in— Yesterday (Monday) we made two runs with Charcoal, the s extending over three hours. I think that the evidence is conclusive t we cannot use charcoal here. To begin with it is next to impossible to the building from catching fire when charcoal is used & on this unt we had to stop running it. We have made very little carbide on e runs, less than one quarter the amount we would have made with . Then the sparks came out to a great distance (6 feet) when we ned the furnace door & this made stoking difficult. The Carbide is of blow holes & looks very much like inferior coke Carbide.

We are running coke & lime now and will not try the al again just at present.

The Pratt & Whitney Co's man is now here setting up the it is likely we may have to stop running for a day or so as we have pty the bins.

I have ordered a shaper for two hundred dollars to plane up arbons with as we cannot any longer depend on the Canadian hine shop for this work. Ordered from Pratt & Whitney a tool 30 s ago, second hand.

Yours,

Horry

igure VI - Facsimile of first known R&D report, dated January 26, 1897, from William S. Horry at Lake Superior Carbide Company in Sault Sainte Marie, Michigan, to George O. Knapp in Chicago

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Figure VII - Union Carbide Company Founders and Management Group at Niagara Falls Gorge in 1911

Front row (standing): 1) Unknown, 2) John Williamson, Chief Engineer of the Peoples Gas Company, 3) George O. Knapp, President of Union Carbide Company, 4) George O. Cox, Niagara Falls Plant Superintendent. Back row (seated): 1) Unknown, 2) Anthony N. Brady, Financier, 3) Edgar F. Price, Vice President of Union Carbide Company, 4) Cornelius Kingsley Garrison Billings, Founder, 5) Isaac R. Edmunds, Chief Engineer of Electro Metallurgical Company, 6) Chester T. Ayres, Works Manager.

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chief metallurgist of the new company. Besides low-carbon ferrosilicon, the Electro Metallurgical Company also made ferrochrome and ferronickel for the manufacture of stainless steel and silicon for alloying with aluminum for use in the aircraft industry.

Union Carbide Company and the Electro Metallurgical Company both required large quantities of carbon electrodes for use in their smelting operations. These were obtained from the National Carbon Company. National Carbon had been organized in 1886 in Cleveland, Ohio, by Myron Herrick and W. H. Lawrence, among others, to make carbon electrodes for street lighting. Lawrence had earlier been associated with Charles F. Brush, who was a pioneer in the electric arc lighting business and had successfully demonstrated the first commercial electric arc light in Cleveland in 1876. The electrodes were made from petroleum coke, which at the time was a worthless byproduct of the Standard Oil refinery in Cleveland. Despite company lore, Brush's association with Union Carbide was not through National Carbon. Brush was involved later in the formation of the Linde Air Products Company, and his connection with Union Carbide and Carbon Corporation was through that route. (The carbon "brushes" in electric motors are named after him.)

National Carbon Company had gotten into the dry cell battery business in 1890. They made and marketed EVEREADY batteries first in the United States and eventually throughout the world. Dry cell batteries have a carbon rod at their center and that was the connection that took them into the battery business. In addition to being used in flashlights, dry cell batteries were widely used to power early telephones and then early radios. In fact, radio batteries became the driving force behind the battery business. As an interesting sidelight, starting with radio station CKNC in Toronto, Union Carbide in Canada established a chain of radio stations in the 1920s and 1930s to stimulate the sale of radio batteries. At the outset of World War II in 1939, the stations were being operated for Union Carbide by an American company. The Canadian government was not comfortable with that situation; therefore they bought out the stations. This action provided Canada with the nucleus around which they formed the Canadian Broadcasting Company. It should also be noted that National Carbon's worldwide manufacture and marketing of EVEREADY batteries in the 1930s provided Union Carbide with a ready entry into overseas markets for other businesses.

National Carbon had been successful from the outset in the carbon electrode lighting business because they had produced a superior product (it was stronger and had a longer life). Now, to make a superior product for furnace electrodes, they acquired the Acheson Graphite Company. Dr. Edward G. Acheson had developed a process for converting carbon into graphite by baking it at high temperature. Graphite made a better electrode than carbon because it had better electrical conductivity and because it was thermally more stable.

Linde Air Products Company

In 1895, Henri le Chetalier, a Frenchman, determined that acetylene and oxygen burned with a very hot flame, hot enough to melt steel. In 1901, Edmond Fouche also a Frenchman, developed a practical blowpipe—or torch—for use in oxyacetylene cutting and welding. As a result of those developments, the demand by the metal trades industries for oxygen and acetylene increased dramatically. Oxygen, however, was not readily available in large quantities. It had previously been generated mostly by the electrolysis of water or by the decomposition of potassium chlorate.

In 1895, Professor Carl von Linde, a German physicist from Munich, developed a successful system to produce oxygen by the low-temperature liquefaction and rectification of air. Professor von Linde had been a pioneer in refrigeration and in 1873 had developed the first ammonia refrigeration machine, which was used to make ice. His cryogenic air liquefaction and separation invention exploited the use of the Joule-Thomson effect, in which a compressed gas cools itself when the pressure is released and it expands. He also used the technique of fractional (stagewise) distillation to separate the liquefied components of air.

Myron Herrick of the National Carbon Company was a personal friend of Professor von Linde. On a visit by von Linde to Cleveland in 1906, Herrick arranged for von Linde to have breakfast with a number of "captains of industry" and to tell them about what he was doing, about what was happening in Europe, and about the conditions under which he would be willing to transfer his rights. Afterwards, Charles F. Brush passed around a sheet of paper asking for signatures of those who would subscribe to buying the American rights to von Linde's process. Thirteen of the fifteen present signed. The next day incorporation papers for the Linde Air Products Company were drawn up and the company was officially

chartered in January of 1907. Both National Carbon and Union Carbide had a stake in the new company.

The first Linde plant in America was built in Buffalo, New York, with a capacity of one million cubic feet of oxygen per month. Over the next several years, plants with capacities of four to five million cubic feet of oxygen per month were built in Cleveland, Detroit, Baltimore, Los Angeles, Brooklyn, Youngstown, Philadelphia, and Pittsburgh. Linde also got into the business of making tanks and apparatus for the distribution and use of oxygen.

Prest-O-Lite Company

A lot of the calcium carbide that Union Carbide Company made went to a company in Indianapolis called the Concentrated Acetylene Company. The company had been formed in 1904 by Carl G. Fisher, James A. Allison, and P. C. Avery. Fisher had a bicycle shop and had gotten interested in acetylene by way of the lights on bicycles. Avery had developed a small portable gas tank for safely holding compressed acetylene. (Compressed acetylene—above 10 psi—was a problem because a spark or a blow could cause it to detonate.) Allison, who was in the automobile business, was the financial resource behind the deal. They set out to supply compressed acetylene in small tanks to the lighting market. Prior to that time, people bought calcium carbide and generated their own acetylene, which was not always convenient. (The acetylene was generated in the lamp itself, which was done by controlling the drip of water on dry calcium carbide in a chamber in the lamp.)

In 1906, Avery sold his share of the company to his two partners, and the name of the company was changed to the Prest-O-Lite Company. The company operated in Indianapolis for several years but the plant was beset by fires and explosions from time to time as acetylene plants in those days were inclined to do. The city required that they move out of town. They chose a rural site west of Indianapolis that became known as Speedway, because Carl Fisher had built a two-and-one-half mile oval brick track next to the plant for testing and racing automobiles. The track today, of course, is the Indianapolis Speedway, the site of the "Indy 500." Carl Fisher sold out to Union Carbide Company for $6 million and used the money to develop the city of Miami Beach from an uninhabited, offshore sand bar in Florida. James Allison went on to form the Allison Motor Company

and produce the famed Allison aircraft engines. (The Allison Motor Company was later bought out by General Motors.)

Prest-O-Lite was very successful in providing acetylene and the necessary tanks and equipment to use it. They built a number of plants across the country. However, as electric lights came into use on cars and in houses, the acetylene lighting business declined. On the other hand, the need for acetylene for cutting and welding was growing, and Prest-O-Lite began filling that need. The safe storage of compressed acetylene in large tanks had been made possible by a discovery in France that acetylene dissolved in acetone in an inert porous filler lost its penchant to detonate, that is, decompose explosively. Inasmuch as acetone is able to dissolve large volumes of acetylene, it made for an effective system. Indeed, this system is still in use today with some modification to the porous filler.

There were natural and growing relationships among the companies involved. Union Carbide Company was making calcium carbide and selling it to the Prest-O-Lite Company, which generated acetylene and sold it. The Electro Metallurgical Company, Union Carbide Company's subsidiary, was making ferroalloys using essentially the same smelting process used by Union Carbide to make calcium carbide. National Carbon Company was making furnace electrodes and selling them to the Union Carbide Company and to the Electro Metallurgical Company. The Linde Air Products Company, owned in part by National Carbon and Union Carbide, was producing oxygen to be used with acetylene for cutting and welding. Further, Prest-O-Lite and Linde were also making and selling equipment for transporting gases and using the oxy-acetylene systems.

Prest-O-Lite was uneasy, however, with being tied to a single supplier of calcium carbide. Therefore, they decided in 1913 to try to find an alternative source of acetylene, preferably from a petroleum source. Inasmuch as they did not have the resources to make such a study, they looked about for help.

Mellon Institute

The secretary of Prest-O-Lite, Frank E. Sweet, was directed to the Mellon Institute in Pittsburgh, which had just been established by Richard B. Mellon and Andrew W. Mellon, Pittsburgh bankers. The purpose of the Mellon Institute was to do research for the sole benefit of industrial sponsors. It filled a need when most industry did not have in-house research and development activities of any note. It

utilized a fellowship system for individual studies and operated in loose association with the University of Pittsburgh. In practice, the industrial sponsor defined the objectives and paid the bills. Mellon provided professional guidance, laboratory facilities, and—with the sponsor's approval—key personnel who would be wholly devoted to the sponsor's program. One key policy of the Institute was that there was to be no competition between fellowships.

In 1913, Mellon established Institute Fellowship 37 for Prest-O-Lite. Its objective was to explore alternative methods for the commercial generation of acetylene. The senior fellow assigned to lead the work was Dr. George Oliver Curme, Jr. Dr. Curme had been born in 1888 in Mount Vernon, Iowa, where his father was a university professor. Curme, the younger, had an undergraduate degree in chemistry from Northwestern University and a doctorate in chemistry from the University of Chicago. He had just recently returned from a year of study in Germany at the University of Berlin and at the Kaiser Wilhelm Institute. Work on the study started in 1914 and lasted three years. In that time, Curme and his associates developed an electrothermic process for generating a mixture of hydrocarbon gases rich in acetylene by subjecting gas oil, a petroleum fraction between kerosene and diesel fuel, to a submerged high-frequency electric arc. The gas produced contained about 25-percent acetylene and about half that much ethylene. It appeared that acetylene produced by this technology could be competitive with acetylene from calcium carbide.

Dr. Curme, being an organic chemist, was also much interested in chemical derivatives of acetylene. However, he had not been permitted to pursue work in this area because Union Carbide Company had sponsored a Mellon fellowship (No. 64) in 1914 to find diversified uses for calcium carbide and acetylene. In fact, they had demonstrated the practicality of the hydration of acetylene to acetaldehyde and processes for the conversion of acetaldehyde to aldol, to acetic acid, and to vinyl acetate. Linde had also sponsored a Mellon fellowship, in 1915, to explore uses for nitrogen, a byproduct of the production of oxygen.

Dr. Curme then turned his attention to ethylene, which also had been made in some quantity in the submerged arc process. There was no conflict here insofar as usage and derivatives were concerned. Furthermore, ethylene in all likelihood could be made cheaper than acetylene. There was also the prospect of using ethylene for a greater number of aliphatic chemicals than had been proposed for acetylene. The most obvious potential derivative was ethanol, ordinary ethyl alcohol,

which at the time was made only by fermentation. And up to Curme's time, the little ethylene that was made was produced by the dehydration of fermentation alcohol. (Some ethylene was also found in an impure state in water gas and as an unwanted byproduct in petroleum refining.)

Ethylene had been discovered in 1795 by four Dutch chemists—Deimann, van Troostwyk, Bondt, and Louwvenburgh—who had prepared it by dehydrating ethanol. From the ethylene, they made ethylene dichloride, which is a heavy liquid insoluble in water. They called the ethylene "olefiant" or "oil forming gas" on the strength of that property. The name survives today as "olefins," which describes a whole series of homologous compounds. In the 1820s, Henry Hennell, working with Michael Faraday's laboratory, reversed the process and made ethanol from ethylene by combining it with sulfuric acid to produce ethyl hydrogen sulfate and then hydrolyzing that with water to yield ethanol. Berthelot conducted the same reaction with propylene to make isopropanol in 1855.

Work on ethylene derivatives at Mellon started in 1917 with Dr. Curme, his brother Henry, plus John N. Compton and Glenn B. Bagley. The area that they chose to explore first was the manufacture of benzoic acid by way of ethylene, ethylene dichloride, and dibenzyl. The experimenters used the Claude process for the separation and purification of ethylene rather than the Linde cryogenic process, because they felt that their work was in conflict with Union Carbide's objectives and in turn with Linde.

Union Carbide and Carbon Corporation

In the meantime, the heavy demands of World War I for steel and alloys had caused growing pains in Union Carbide, Electro Metallurgical, National Carbon, Prest-O-Lite, and Linde. The interrelationships were so tight that any upset in one of the group translated quickly to the rest. As a result, National Carbon proposed a merger. There was already some interlocking ownership, anyway. (Union Carbide owned 40 percent of Prest-O-Lite's stock and 30 percent of Linde's stock.) They generally felt that a merger would be beneficial all around. Union Carbide had furnaces and strategic materials, top notch management, and capital. Some of the directors of National Carbon were looking to retire, and Carl Fisher of Prest-O-Lite wanted to get on with his development of Miami Beach. Linde needed help in the form of capital and technical management. A merger was deemed natural,

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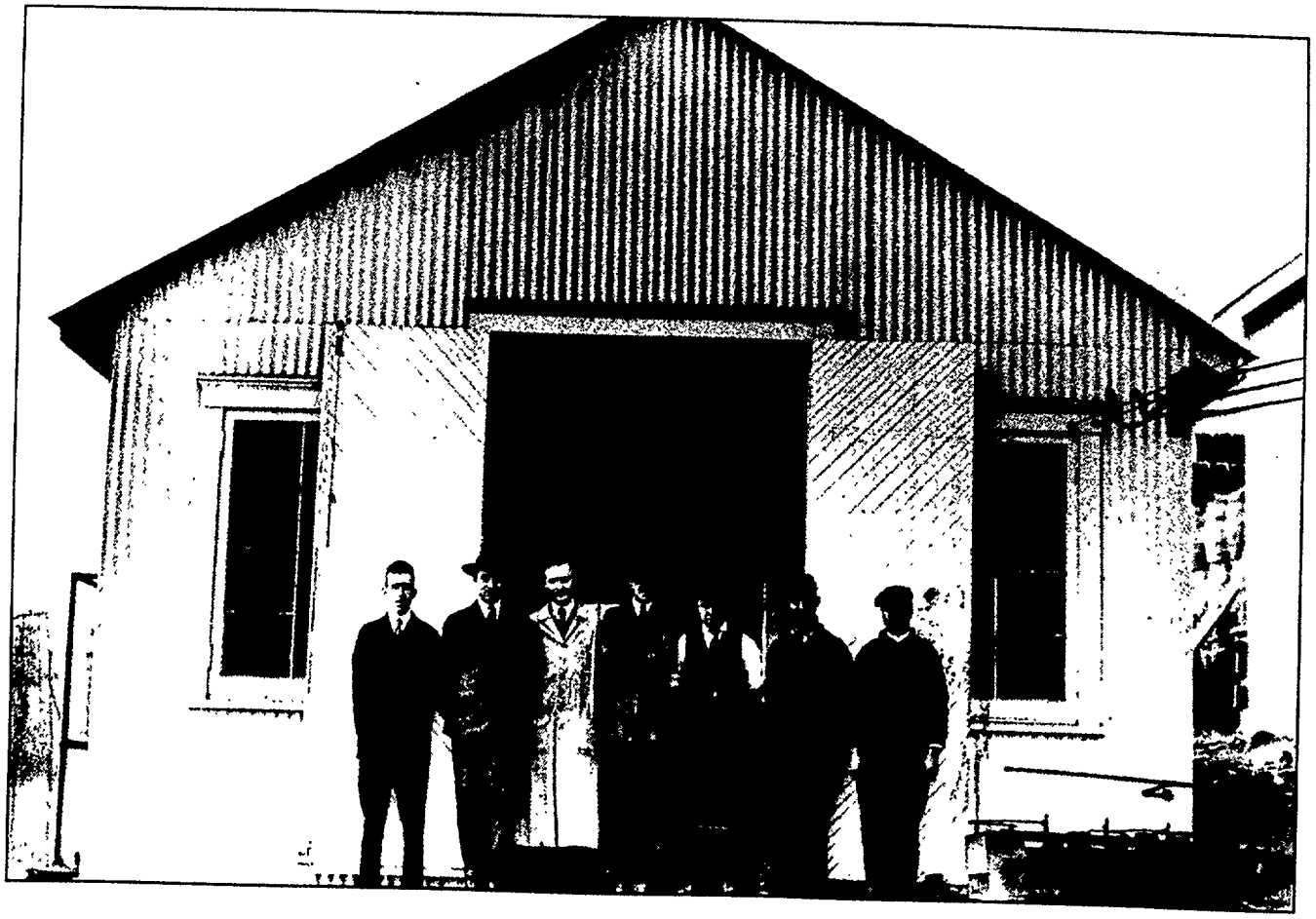


Figure VIII - Laboratory Known as the "Shack" at the Mellon Institute in 1917
Individuals left to right: Glenn D. Bagley, George O. Curme, Jr., Henry R. Curme, John N. Compton. Others unidentified.

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functional, and logical. So, on November 1, 1917, Union Carbide and Carbon Corporation came into being.

The new entity was formed as a holding company capitalized at $79 million with Myron T. Herrick of National Carbon as chairman and George O. Knapp of Union Carbide Company as president. Among those on the board of directors were C. K. G. Billings of the Peoples Gas Light and Coke Company, Jesse Ricks, a lawyer, and Edgar F. Price, the former farm boy from Spray. Ricks had represented Union Carbide Company interests for some years and had put the deal together without any underwriting fees being involved. (The story goes that some of the principals were parishioners of the same church in Chicago and had struck the agreement to form the Company on the church steps after Sunday services.) The financial men behind the merger were Cornelius Kingsley Garrison Billings and his associate, Anthony N. Brady. They held large blocks of stock in Union Carbide Company and controlled the action. However, the largest block of stock was taken by John Motley Morehead. Headquarters for the new company were established in New York City with other offices in Chicago.

The merger appeared to signal the end of the Prest-O-Lite fellowship at Mellon, because now Presto-O-Lite and Union Carbide were tied together and Presto-O-Lite no longer needed an alternate source of acetylene. However, a demonstration of the submerged arc process had been scheduled for Prest-O-Lite management and it proceeded anyway. The demonstration was also attended by representatives from Union Carbide Company, and included John Motley Morehead. The reaction was favorable but noncommittal.

At about this same time, Dr. R. F. Bacon, the Director of the Mellon Institute, was appointed as technical head of the United States Army's Chemical Warfare Service. In this position, he was seeking to develop a new source of ethylene for the manufacture of dichloroethyl sulfide in support of the war effort in Europe. Ethylene for its manufacture was being made by the dehydration of ethanol, which was in short supply. Bacon was aware of Curme's work, and he approached him about the possibility of making ethylene from gas oil by the electrothermal process. Dr. Curme, however, suggested using ethane instead, a gas in abundant supply, inasmuch as it required less power to crack, and electrical energy was in short supply. As a result, at the instigation of the Chemical Warfare Service, the Mellon Prest-O-Lite fellowship took on a program to explore the manufacture of dichlo-

roethyl sulfide from ethylene dichloride derived from ethylene.

The first efforts were devoted to the ethylene chlorhydrin process, and work was also started to convert propylene to isopropanol. The fellowship now had the advantage that it had the resources of the Linde Company with its low-temperature separations technology as a partner. A small scale model of the proposed unit was set up at the Linde laboratory in Buffalo, New York. It consisted of an electrically heated silicon tube to crack ethane and a low temperature liquefaction and separation unit. Suitable conditions and yields for the manufacture of ethylene were demonstrated. In the summer of 1918, work was started on a small "commercial" ethylene plant at Buffalo. The job was nearly complete in November when the war ended and the demand for dichloroethyl sulfide evaporated.

Carbide and Carbon Chemicals Corporation

During the year following the Armistice (November 11, 1917), the program hung in the balance. The post-war uncertainty and confusion contributed to the situation. Also, no one in the organization other than Dr. Curme seemed to know anything about manufacturing chemicals. However, studies had indicated that there were promising markets for ethylene dichloride, ethanol, ethylene glycol, isopropanol, and acetone. Earlier, Dr. Curme had proposed to the new corporation that:

> "Starting with a plentiful supply of ethylene and acetylene, and the necessary by-products obtained in the manufacture of these substances, a huge chemical industry can be built up capable of absorbing thousands of tons of products annually. The Union Carbide and Carbon Corporation with control of the Linde process, the Carbide process, and with its knowledge and control of electric power projects, is in an exceptional position to exploit this field."

Toward the end of 1918, it was decided that a thorough review should be made of the program, its prospects evaluated, and a decision made to either continue or not. A week of intensive figuring was spent by Dr. Curme and John N. Compton. They put together a set of estimates and presented them in New York. The decision was made to continue. The estimates proved to be faulty, in part, because they were based heavily on the sale of diethyl sulfate at $1.00 per pound—

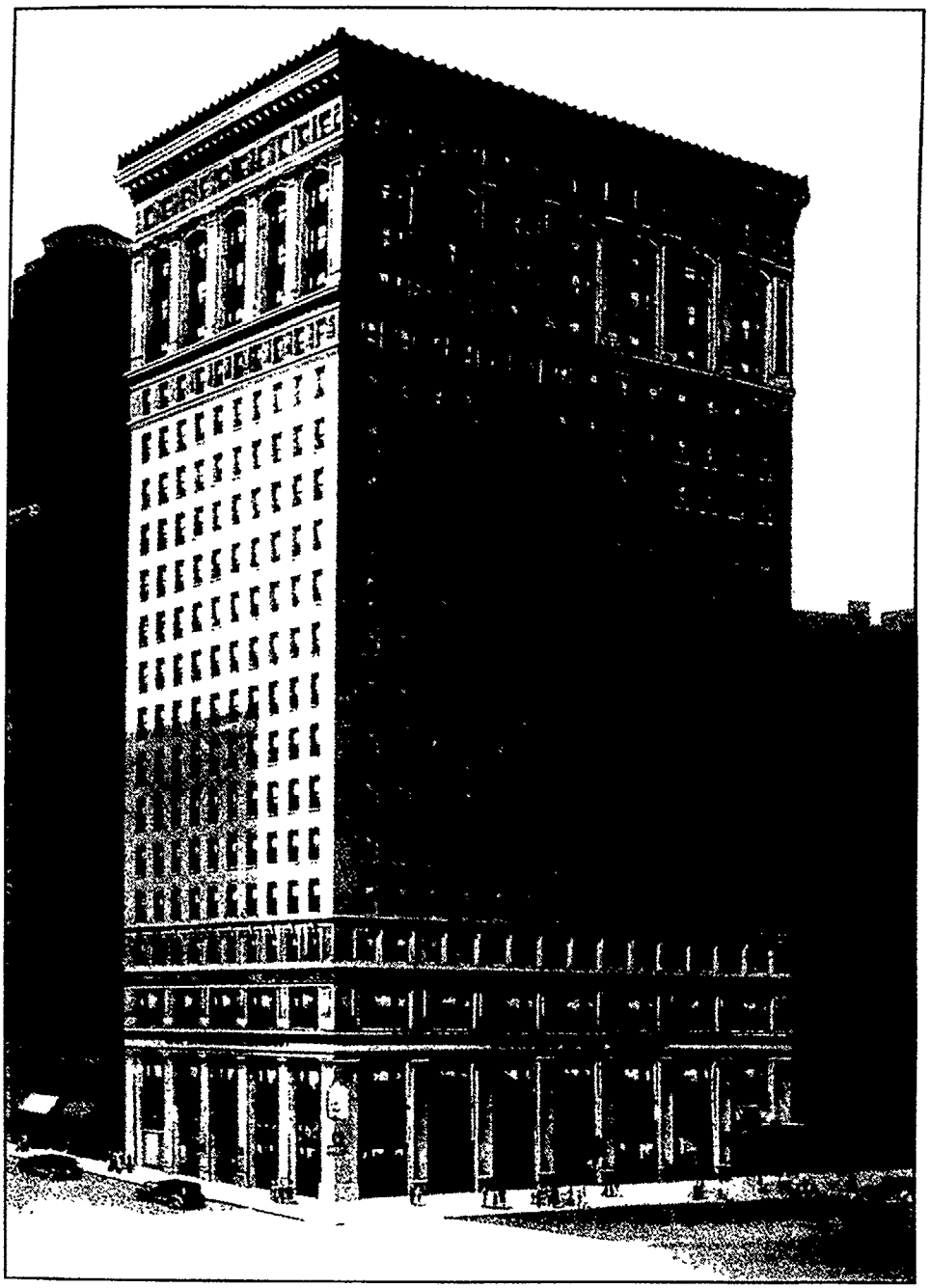


Figure IX
Union Carbide Corporate Offices 1917 - 1959
42nd Street and Madison Avenue, New York, NY

which was a product that didn't sell until 1957. What really was bought, however, was Dr. Curme's vision of an aliphatic chemicals industry. The ultimate sponsor at the Corporate level was Edgar F. Price, a vice president of the Corporation and one of the original employees at Spray. Without him, Curme's vision would have died.

As a result, it was decided that work should continue on ethylene and derivatives for both commercial uses and possible national defense needs. The new project was to function as a division of Linde with W. F. Barrett, then a vice president of Linde, at its head. James A. Rafferty, an assistant works manager at Linde, was made the full-time manager of the project. H. Earle Thompson was brought in from Linde and made the principal technical adviser with the overall responsibility for engineering. Dr. Curme and his associates were still part of the Mellon Institute.

The acetylene studies were put on the shelf, and work was started at Mellon to build ethylene facilities and a unit to make diethyl sulfate, a precursor to ethanol and ethylene chlorhydrin. A small unit to make isopropanol was also set up at Linde in Buffalo and fifteen gallons made. The first ethylene from the new system was made in January of 1920. There was some trepidation about compressing ethylene because it never had been done before and its counterpart, acetylene, was prone to detonate. Therefore, the first ethylene compressor was tested in an open field at a safe distance from all concerned. Fortunately, ethylene proved safe to compress. Operations were carried out in a combined continuous and batch manner between Mellon in Pittsburgh and Linde in Buffalo.

Fire destroyed the pilot plant at Buffalo in May of 1920. Its reconstruction was deemed inadvisable, and a new site was sought. Rafferty was given the responsibility for finding it, and he explored locations in West Virginia, because of the quantity and quality of natural gas there. One of the sites was at Clendenin, a hamlet on the Elk River about twenty miles above Charleston, which was the location of the Clendenin Gasoline Company. The company was a small gas processing plant that had contracts to take natural gas collected from wells, process it to remove the accompanying gasoline by absorption, and return the stripped gas, methane, to a public utility. It operated on a self supporting basis by selling the gasoline. However, the gasoline produced was "wild," that is, it contained dissolved volatile gasses —ethane, propane, and butane. These were partly removed before the gasoline was sold by letting them "weather off" to the atmosphere from open storage tanks. The wasted ethane and propane, however, were just the mate-

rial that was needed as feedstocks for the manufacture of ethylene and propylene. In effect, they could be had for free from the Clendenin plant. Accordingly, the plant and some adjacent land were purchased. The plant continued to be held under the name Clendenin Gasoline Company to avoid the need to establish new contracts with sellers and buyers. (The Clendenin Gasoline Company continued in existence until 1938.)

In mid-1920, Carbide and Carbon Chemicals Corporation was formed to take over the project. The petrochemical industry had been born. Rafferty was named general manager and Curme chief chemist.

People

What happened to the major players along the way? Thomas Leopold Willson went back to Canada where he made calcium carbide, promoted fertilizer and hydroelectric projects, and made and lost a fortune. He died on a business trip to New York in 1915 at the age of 55.

Major James Turner Morehead paid off his debts, regained a small fortune, and died in 1908 at age 66.

John Motley Morehead served as a construction engineer and consultant to the calcium carbide industry for several years. In 1902, he joined Peoples Gas Light and Coke of Chicago as chief chemist. He subsequently became affiliated first with Union Carbide Company and then with Union Carbide and Carbon Corporation. Along the way he acquired a considerable fortune. He was the largest single stockholder in the Corporation when it was formed. He distinguished himself early on in the field of gas analysis, and continued to serve as a consultant in Union Carbide Corporation. In the 1940s, he experimented successfully with making synthetic gemstones in the Linde laboratories at Tonawanda, New York, which he funded out of his own pocket. The gemstones were marketed first as instrument bearings and then as Linde "Stars." Morehead went to the office daily in New York and never retired. He died in 1965 at age 94. He was a major benefactor of the University of North Carolina, donating about $30 million to the school during his lifetime. He also served as mayor of Rye, New York, from 1925 to 1930, and as the United States Envoy Extraordinary and Minister Plenipotentiary of Sweden from 1930 to 1933.

Guillaume de Chalmot, the developer of the calcium carbide process and

the ferroalloy processes, died in 1899 at the age of 29, possibly of tuberculosis. He was manager of the Willson Aluminum Company Holcomb Rock plant at the time.

Edgar F. Price, hired in 1891 by Major Morehead at Spray, became president of Union Carbide Company and then a vice president and director of Union Carbide and Carbon Corporation. He was consistently supportive of the chemicals programs. He retired in 1925.

Cornelius Kingsley Garrison Billings, the financial strength behind the new corporation, was a noted horseman and had a 4000-acre horse farm in Viginia. He also had an estate in New York City (The Cloisters, which was sold in 1925 to John D. Rockefeller, Jr. who donated it to The Metropolitan Museum of Art), and estates on Long Island and at Santa Barbara, California. He became a member of the board of directors of Union Carbide and Carbon Corporation when it was formed in 1917 and served until his death in 1937 at age 76. He was chairman of the board from 1929 to 1937.

James A Rafferty, whose roots were in Peoples Gas Light and Coke Company, had joined Linde in 1917 and moved over to Carbide and Carbon Chemicals Corporation in 1920. He was elected president of the Chemicals group in 1929 and became a director of the parent corporation in 1941. Although he was a mechanical engineer and a chemist, he was not directly involved in the front line of the Company's technology. Nonetheless, his was the guiding hand behind the selection of people and the support of programs that made the chemicals show go. He was recognized as a prime mover in the petrochemicals industry in 1948 when he was presented the Chemical Industry Medal by the Society of Chemical Industry. He died in 1951 while still active with the Company.

George Oliver Curme, Jr. joined Carbide and Carbon Chemicals Corporation from the Mellon Fellowship in 1920 and went on to be vice president-research and a director of Union Carbide Corporation. He provided active direction of the Company's technical programs. He held numerous patents, including those for the manufacture and purification of ethylene, the manufacture of ethylene dichloride, the manufacture of acetaldehyde, the manufacture of acetic acid, the manufacture of ethylene glycol, the manufacture of ethylene chlorhydrin, and the manufacture of acetylene from organic liquids. Along the way, he received the Chandler Medal from Columbia University in 1933, the Perkin Medal from the Society of Chemical Industry in 1935, the Elliot Creeson Medal from the Franklin Institute in 1936, the National Modern Pioneer Award from the National Association of Manufac-

turers in 1940, the Willard Gibbs Medal from the American Chemical Society in 1944, and the National Medal of Science in 1976. Curme retired in 1955, although he continued as a director of the Company until 1961. He died in 1976 at the age of 87.

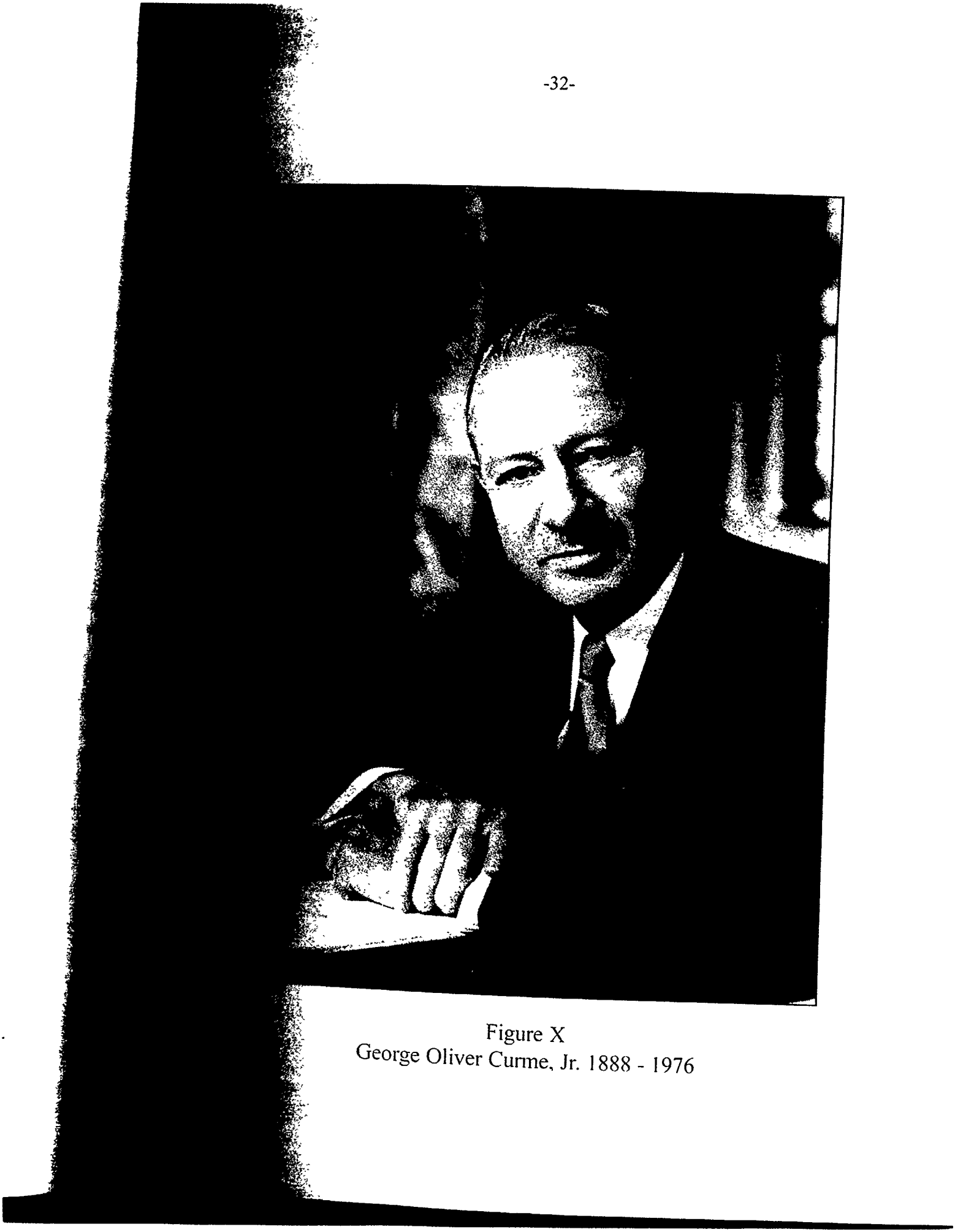


Figure X
George Oliver Curme, Jr. 1888 - 1976

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Chapter Two
PETROCHEMICAL PIONEER (1920-1940)

In these early years, Union Carbide and Carbon's fortunes were in ferroalloys, electrodes, acetylene, and oxygen, and were tied heavily to the steel business and the metal working industries. Chemicals and plastics were the tail that eventually wagged the dog. Prior to the introduction of ferroalloys, most steel had been ordinary carbon steel, differentiated mainly by its carbon content. Ferroalloys imparted steels with special qualities such as greater strength and hardness, increased ductility, and resistance to corrosion, abrasion, and deterioration by heat. The Electro Metallurgical Company was the pioneer in the field and dominant in the industry. Its products included ferrochromium, ferrosilicon, ferromanganese, and ferrozirconium. Considerable quantities of material were involved. In 1907, when the Electro Metallurgical Company was formed, only a negligible quantity of steel was alloy steel. By 1929, the amount of alloy steel produced had risen to three million tons per year and was growing. The alloy content of these steels ranged from as little as several percent for low-alloy steels to over one-third for stainless steels.

Increased production of calcium carbide and ferroalloys in electric arc furnaces increased the demand for carbon and graphite electrodes from National Carbon. In addition, alloy steels were also being made in electric arc furnaces and this also increased the demand for carbon and graphite electrodes. Graphite electrodes were in particular demand, because they were better able to withstand the tremendous thermal shocks encountered in electric arc furnaces. Graphite electrodes were also being made for search lights and beacons and for motion picture photography and projection. (Union Carbide won an "Oscar" from the motion picture industry in the late 1930s for its projector electrodes.) In addition, carbon electrodes were being made for electric welding and for the electrolytic production of chlorine and aluminum.

Union Carbide Company also was producing ever increasing quantities of calcium carbide to make acetylene for welding and for metal fabrication. (Previously, most steel tanks, boilers, buildings, railroad cars, ships, and so on, had been

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assembled by hot riveting.)

Linde was keeping pace with oxygen and other gases. To keep up with demand, Linde in 1935 introduced the DRIOX system. This was a revolutionary concept to deliver liquid oxygen, rather than compressed gas, in tank cars. In this fashion, the quantity of oxygen that could be shipped in a railroad tank car (25 tons) was ten times as much had been possible previously with gaseous oxygen. Handling and distribution costs were reduced dramatically. In addition to producing oxygen and nitrogen, Linde also began separating the rare gases from air and selling them. These included argon, neon, krypton, and xenon. During the first World War, Linde had pioneered a process in Texas for recovering helium from natural gas for use in dirigibles, and it continued to produce helium for sale. Uses for these gases included shielded welding and electric signs. The Linde experience in rectifying these gases (separating by staged distillation) translated well to the new petrochemicals business.

Union Carbide's business had carried it to Canada from the earliest days for the manufacture of calcium carbide and the production of carbon electrodes. The draw to Canada was both markets and inexpensive hydroelectric power. Canada was also a market for other Company products. However, Canadian business generally was consolidated with domestic operations for reporting purposes, and the first business foray "overseas" was in 1915 at Sauda, Norway, near Bergen. The Electro Metallurgical Company established an operation there to serve European markets and take advantage of inexpensive hydroelectric power. Both ferroalloys and calcium carbide were made.

In 1932, National Carbon established plants in Monterey, Mexico, and Shanghai, China, to make EVEREADY batteries and flashlights. The real demand, however, was not so much for flashlights as for batteries for radios. In 1933, an EVEREADY battery and flashlight plant was built in Batavia (now Jakarta) in the Dutch East Indies (now Indonesia). These were the first of a long series of foreign operations. By 1939, Union Carbide had plants for the manufacture of ferroalloys, electrodes, and plastics in Norway, Sweden, England, France, and Italy. It had plants for the manufacture of EVEREADY batteries and flashlights in Argentina, Australia, China, India, Java (Indonesia), Mexico, New Zealand, and South Africa. These early foreign operations facilitated the entry of other Union Carbide businesses overseas after the Second World War. One of the British affiliates, in later years, employed a chemist who would become Prime Minister of Great Brit-

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ain, Margaret Thatcher.

Clendenin Plant

In 1920 Dr. George Oliver Curme, Jr. had an array of plans, estimates, and projects drawn up for the launch of the Clendenin operation that was most impressive and, as he thought, complete in every detail. "To be true," he remarked later, "we had not provided for raw materials, markets, financing, engineering, operations, shipping, publicity, accounting, and a few such items...but we thought we were ready to go." They did have some good ideas, though, and confidence, and the timing was right and go they did.

Construction work at Clendenin was finished and operations started in the summer of 1921. In the meantime, the post war business boom had collapsed and business prospects were uncertain. Nonetheless, the Company committed to spending money on the project despite the fact that other expenditures were curtailed. A substantial mitigating factor was the booming sales of PYROFAX gas, essentially pure propane bottled for use in industry and for home heating and cooking. The propane was being produced in the course of recovering feedstocks from natural gasoline for the Clendenin operation. The use of PYROFAX was very popular, and a ready-made organization, Linde's Prest-O-Lite group, was available for bottling, selling, and distributing the product through its bottled oxygen and acetylene operation. Indeed, this was the beginning of the liquified petroleum gas (LPG) business. (Several other small companies were also beginning to sell hydrocarbon gases on a local basis for home use. However, they supplied a variable mixture of gases rather than pure propane or a consistent mixture of propane-butane as PYROFAX did. The Company bought out some of these small competitors and soon offered PYROFAX on a nationwide basis.)

The Clendenin plant was basically a small, works-scale operation and never intended as a fully commercial manufacturing operation. It had several purposes. One was to develop the new tubular, cracking process for olefins plus the separation steps. Another purpose was to develop manufacturing processes for some ethylene derivatives. A third was to produce enough product for market development—or more accurately, to find uses for largely unknown materials. The fourth purpose was to evaluate the various elements of the business and set some directions for the venture.

The first purpose was met reasonably well. The basic gas cracking was successfully demonstrated in three-inch diameter tubes in a gas-fired refractory furnace, and a new, higher pressure gas separation process was devised for the recovery and separation of cracked furnace gases. This new process was more economic, because it operated at higher temperatures than the cryogenic, Linde process that had been used.

The most important derivatives work that was done was on the manufacture of ethylene chlorhydrin, which was then a precursor of ethylene oxide and ethylene glycol. Work was also done on manufacturing isopropanol and diethyl sulfate. A lot of work was also done on processes, such as diethyl sulfate, that were either not commercialized by Union Carbide or just didn't pan out. When pressed as to what was being made at Clendenin, Dr. Curme wryly allowed that it was a lot of mistakes. (A tank car of diethyl sulfate was finally sold some twenty five years later.)

Objectives evolved as the work at Clendenin progressed. At the outset, it was felt that the central features of the venture would be the production and sale of PYROFAX gas, which indeed was extremely successful, and the manufacture of acetone from isopropanol. Acetone was a safe bet, because there was a substantial internal demand for it as a solvent in Prest-O-Lite's acetylene business, and the acetone being used at the time was all purchased and derived by fermentation. It further was subject to wide swings in cost and availability. Synthetic ethanol was always in the picture, too. However, apart from PYROFAX gas, isopropanol, acetone, and ethanol all took a back seat to other products in the actual scheme of things. PYROFAX gas, really more a part of the feedstock program, remained a central feature and provided the bulk of the income for the chemicals operations in the early 1920s. Indeed, the PYROFAX business was so successful that it tended to restrict the availability of feedstocks for the Clendenin operation.

A key to the success of the whole operation was the development of a gasoline stabilizer column. This column, invented and patented by H. Earle Thompson, took "wild" natural gasoline and separated and recovered the light ends (ethane, propane, and butane) by rectification (stage-wise distillation). The concept seems simple today, but much of the oil field industry was still in the dark ages at the time and innocent of any knowledge of rectification. Light ends were removed by "weathering," a process whereby the "wild" natural gasoline was placed in an open storage tank and the light ends allowed to "weather off," that is, be lost to the atmo-

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sphere along with a substantial portion of the gasoline itself. The gasoline stabilizer served not only to recover the light ends and the vented gasoline, but also presented the Company with an opportunity for licensing to oil field operators and others. A lot of effort was put into designing and installing stabilizer columns for oil companies across the country, and a fair amount of income was realized. Unfortunately, the Company's patent was eventually disallowed on the basis that the process was only straight forward technology, and the efforts to sell it were perforce dropped. Nevertheless, the stabilizer column remains a standard of the industry.

Ethylene derivatives made at Clendenin and which provided the actual basis for further commercialization were: ethylene dichloride, ethylene oxide, ethylene glycol, glycol diacetate, and CELLOSOLVE. CELLOSOLVE is Union Carbide's trade name for the solvent ethylene glycol mono ethyl ether, too much of a mouthful to be used in ordinary conversation. The dichloride, oxide, glycol, and diacetate processes had been invented by Curme and his associates at the Mellon Institute. In this particular case, ethylene glycol was made directly from ethylene chlorhydrin rather than by hydrolyzing ethylene oxide. Ethylene oxide was also made from ethylene chlorhydrin.

CELLOSOLVE is a member of a family of solvents called glycol ethers. It had first been envisioned as a solvent for foodstuffs or carnauba wax, but was not suitable for either purpose. Instead, very fortuitously, it proved to be an ideal solvent for nitrocellulose lacquers, which were beginning to be used in large quantities for painting automobiles. CELLOSOLVE is made by reacting ethylene oxide with ethanol. The process for its manufacture was developed and patented by Dr. Charles O. Young at Clendenin. CELLOSOLVE proved to be an early star of the chemicals business.

Ethylene glycol, another star, was finding use in the manufacture of glycoldinitrate, a substitute for nitroglycerine in dynamite. Nitroglycerine tended to freeze in cold weather and separate from the filler in dynamite, rendering it very hazardous. Ethylene dinitrate served the same purpose as nitroglycerine without freezing. Furthermore, the price of glycerine—used to make nitroglycerine—tended to vary considerably with agricultural prices. Ethylene glycol was more than competitive, cost-wise. Ethylene glycol was also finding use as a permanent antifreeze in automobiles under the trade name PRESTONE. It became popular only

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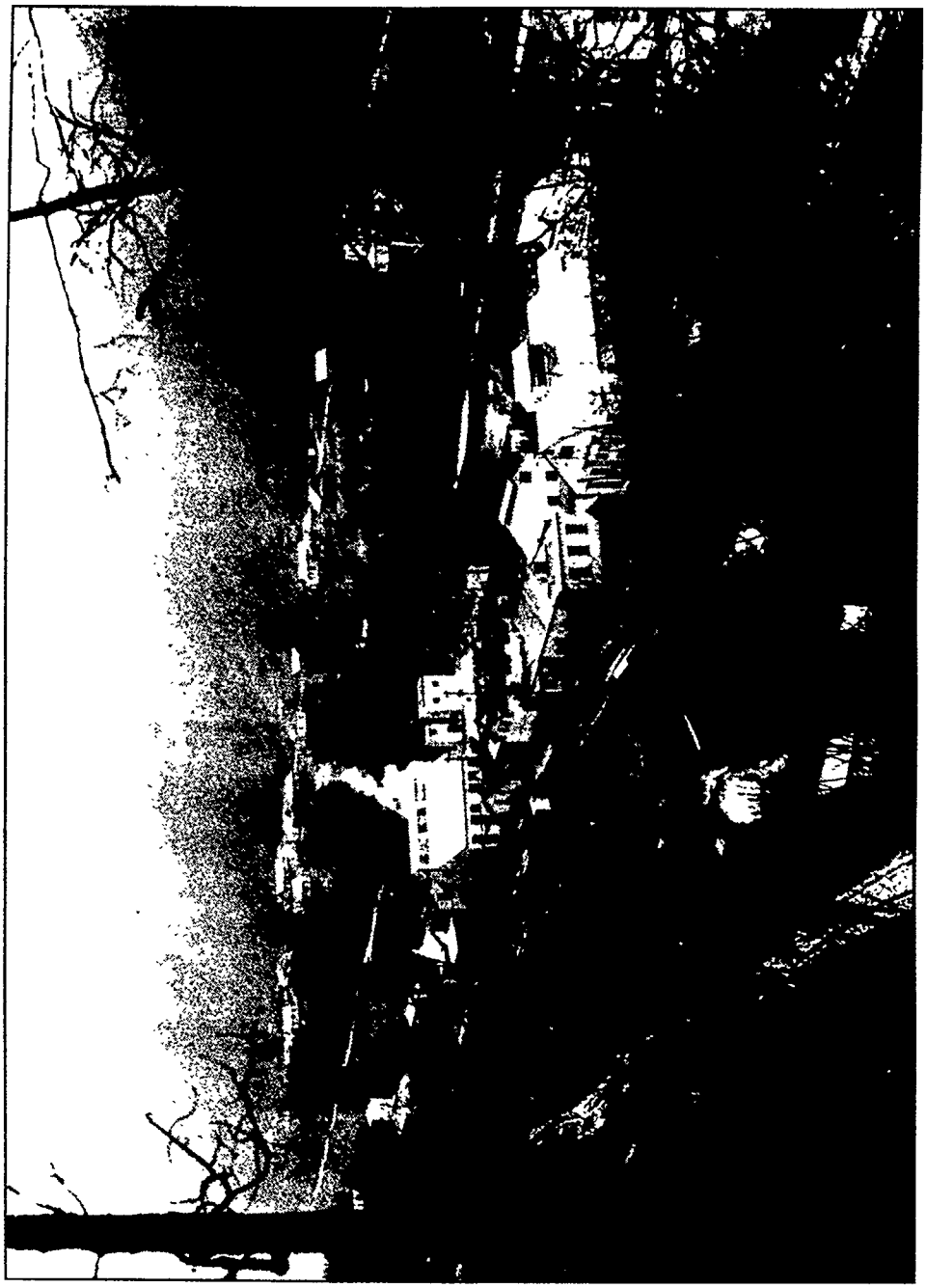


Figure XI
Clendenin Gasoline Plant in 1921

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after inhibitors were added to prevent corrosion. The sale of PRESTONE was facilitated by handling it through National Carbon's EVEREADY battery marketing organization.

Work was also done on the manufacture of acetone from isopropanol and the manufacture of butanol from crotonaldehyde. This work was done, however, in the Corporation's newly established laboratory in Long Island City in New York by Dr. Charles O. Young and H. C. Holden, who had transferred there from Clendenin. Crotonaldehyde is made from acetaldehyde which, in turn, can be made from acetylene.

South Charleston Plant

By 1923, it was obvious that the time had come to enter the chemicals business on a fully commercial basis. New facilities were needed and added sources of raw materials had to be developed. Site surveys were made, and a defunct chemicals plant in South Charleston, West Virginia, the Rollins Chemical Company, was selected as the new location. Rollins, which had made chlorine derivatives and barium products, had the necessary plant infrastructure (steam, water, laboratories, offices, maintenance facilities) to get started quickly and inexpensively. On November 30, 1923, the Rollins plant was leased for five years with options to renew and purchase. Work started on the site in early 1924 to clean it up and make it ready for use.

Facilities planned for the new plant included an Olefins Unit to make ethylene and propylene, an Isopropanol Unit, an Acetone Unit, an Ethylene Chlorhydrin Unit, an Ethylene Oxide Unit, an Ethylene Glycol Unit, and a CELLOSOLVE Unit. It was also intended that ethanol be made at a later stage, but in the meantime, fermentation ethanol would be purchased to make CELLOSOLVE. However, a combination of factors changed the mix almost immediately. First, the strong demand for CELLOSOLVE and ethylene glycol was projected to utilize the entire output of the Olefins Unit (propylene would be cracked to make more ethylene.) Second, there was a sharp drop in the price of fermentation-based acetone, from $0.20 per pound to $0.12 per pound, that was made by acetone producers as a preemptive move to discourage the impending competition from synthetic acetone. As a result, plans were changed in mid-construction to defer the isopropanol and acetone units. The planned capacity of the Olefins Unit was 500,000 cubic feet of

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ethylene per day or the equivalent of 12½ million pounds per year on a 350 day basis. It had also been planned to continue the operation of the Rollins chlorine units for ethylene chlorhydrin operation. However, this was also changed and it was decided to purchase all of the needed chlorine from the Warner-Klipstein plant next door. This was somewhat risky, because Warner-Klipstein was in a rather poor business situation at the time. However, Warner-Klipstein prospered on the strength of the new business and became one of the largest chlorine plants in the country. (It later became Westvaco—not the forest products company of today—and ultimately a part of the FMC Corporation.)

Arrangements were made to obtain additional feedstocks for the new plant. This involved contracting for natural gas concentrates (ethane, propane, butane) from natural gas pipeline companies—mainly the United Fuel Gas Company—and building facilities to extract the concentrates from natural gas. The facilities needed to extract the feedstocks and transport them rivaled the main plant facilities. At the outset, the recovered concentrates were shipped to South Charleston in pressurized railroad tank cars. To do this, a new type car had to be designed and approved by the US Bureau of Mines before they could be built. This type of "V" car is still in service. Later, pipelines were installed to carry the concentrates to South Charleston.

It was also necessary to establish a sales staff. Most of the petrochemicals marketing to date had been done by Dr. Curme, Rafferty, and others of their ilk on an ad hoc basis. Mostly, they had been seeking uses for the new products. Now it was necessary to sell the plant output. Rafferty had been advised to use "professional" salesmen, 1920s style, for the job. Instead, the first salesman that he hired was Dr. Joseph G. Davidson, a Ph.D. chemist from the Mellon Institute. (Dr. Davidson would eventually become President of Union Carbide Chemicals Company.) This pattern was followed throughout the subsequent years. Technically trained salesmen were hired and then oriented at the Mellon Institute to market the Company's products. Orientation in later years would be at Tarrytown, New York, Technical Center. The focus was on applications and service rather than glad handing and order taking.

In November of 1925, the plant at South Charleston was ready for operation. James W. McLaughlin was named Plant Superintendent (Plant Manager). The plant at Clendenin was still running to meet sales demands, and the technical staff was stretched thin trying to operate one plant and get the other started up.

According to John N. Compton, who had been at Mellon and Clendenin and who now headed the local engineering effort, "the months that followed were the most trying and most arduous in the entire history of the Corporation." The step-up from Clendenin operations was large and there were mechanical troubles of every sort in the newly conceived and constructed units. Almost everything had to be invented or adapted for chemical plant service—there had not been much existing equipment or technology to draw on. The operation of the Olefins Unit was erratic, efficiencies in the glycol process were poor, and it was difficult to keep the chlorhydrin-glycol chain of operations going. In spite of all that, plant ratings were maintained most of the time! (The rated capacities were presumably conservative.)

The CELLOSOLVE Unit went into operation early in 1926, and demand was so high that plans were made to expand the entire chlorhydrin products department by six fold. By the end of 1926, the production of ethylene chlorhydrin was three times the design rate, and by the end of 1927, it was seven times the original design rate. CARBITOL, another solvent in the glycol ether family, was added in 1928. It, too, proved successful. CARBITOL is made by reacting ethylene oxide with CELLOSOLVE.

The year 1926 was a period of confusion, intense hard work, and long hours for everyone concerned. However, by the end of the year, the chemicals business was making a profit and "standing on its own feet." Plans were underway for a major expansion. More land was purchased around the plant in 1927 and Blaine Island, an 80 acre tract in the middle of the Kanawha River, was also purchased. Added raw materials were provided by installing stabilizer columns in four natural gasoline plants owned by the United Fuel Gas Company. This time, the concentrates were transported to the plant by pipeline. The provision of concentrates began to be separated at this time from the PYROFAX business inasmuch as each operation was successful in its own right and each needed its own secure source of supply. Attention was also given to refinery off gases as an alternate source of feedstocks. (Standard of New Jersey—now Exxon—had been using refinery off-gases since 1919 as a source of propylene for the manufacture of isopropanol.) To this end, a small oil cracking plant and gasoline refinery was installed on Blaine Island in cooperation with the Pure Oil Company. The facility, known as the Gyro Unit, provided the necessary experience for the use of off gases later at plants in Whiting, Indiana, and Texas City, Texas. It also provided feedstocks for the South Charleston Plant and gasoline for sale.

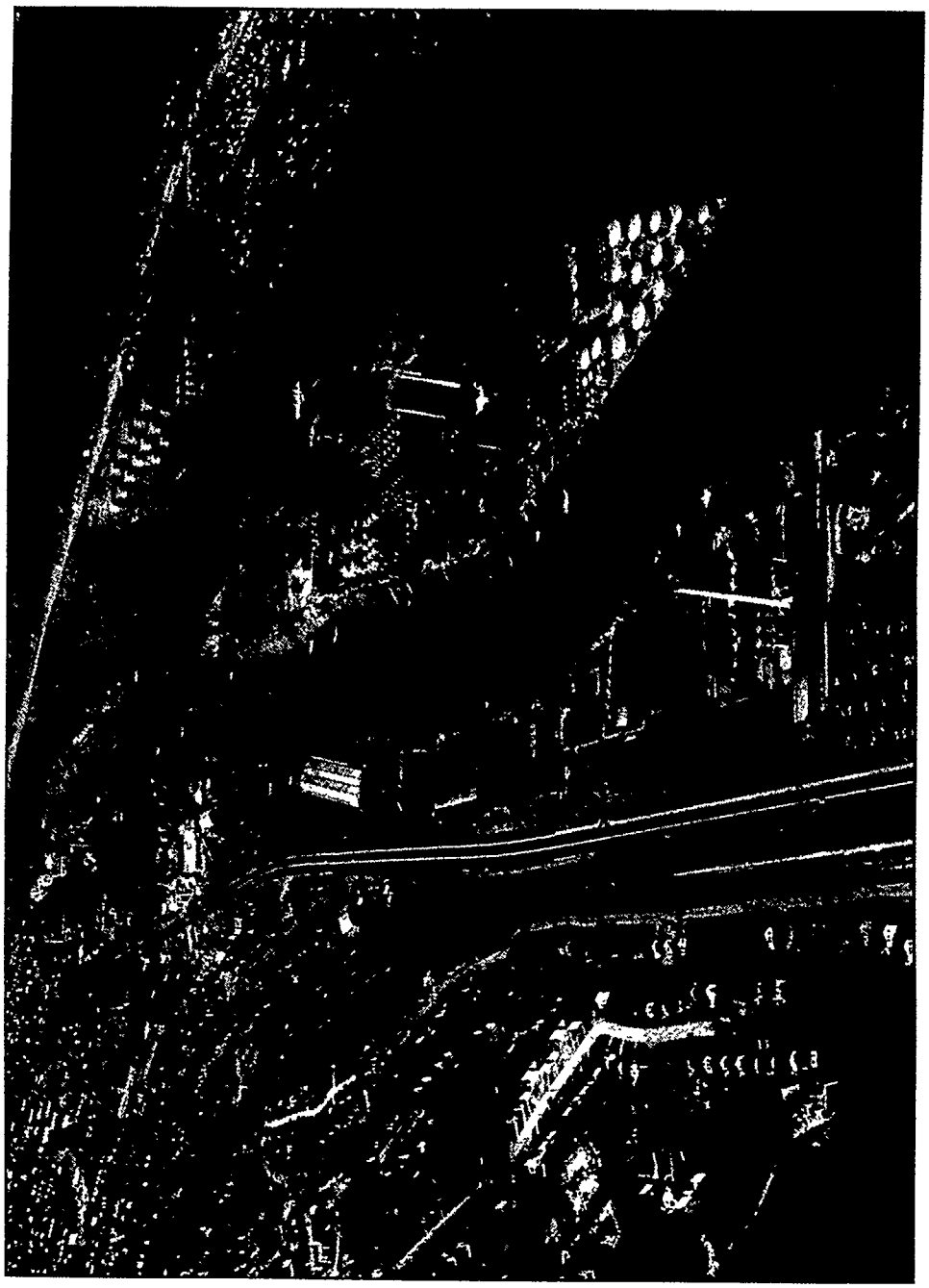


Figure XII
South Charleston Plant in 1962

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The year 1927 was a watershed. Efforts were underway for major expansions, which now included ethanol, isopropanol and acetone. However, in the early hours of January 1, 1928, there was an explosion and fire in the gas separation unit. No one was seriously hurt, but the entire plant was shut down. Many of the plant's technical staff were at a New Year's Eve party at the Ruffner Hotel in Charleston, and tales abound of their rushing to the plant in tuxedos in the snow and cold to put out the fires. In spite of the damage, temporary facilities were quickly rigged and the plant was soon back in limited operation.

A revamped and enlarged Olefins Unit was designed to take the place of the damaged unit. Essentially, it was a bigger unit built in the same place, and it was constructed piecemeal to allow for continuing operations. The rebuilt unit was called Olefins Unit No. 2 and had a capacity of 2,500,000 cubic feet per day of ethylene, equivalent to 65 million pounds per year. Work was completed by the end of 1928. A new ethylene glycol unit was also built.

The planned isopropanol-acetone unit was completed and operations begun in February of 1929. The unit was shut down temporarily in May and modified for a test run to manufacture ethanol. The test was successful and the unit returned to its original purpose. As a result of the test, an ethanol plant was built in 1929 and put into operation in 1930. This was the first successful commercial synthetic ethanol facility in the world, a real feat in light of determined but unsuccessful efforts to do the same thing in Germany, France, and England over the preceding ten to fifteen years.

With a low-cost captive source of ethanol, related derivatives became attractive. One was the manufacture of acetaldehyde, which can be made by the dehydrogenation of ethanol. The alternative route to acetaldehyde was through the hydration of acetylene, which is more expensive. (Acetylene was the principal source of acetaldehyde in Europe.) Most of the acetaldehyde being made from acetylene was produced by the Niacet Chemicals Corporation, and it was derived from acetylene made from calcium carbide. Inasmuch as Niacet was partially owned by Carbide and Carbon Chemicals Corporation, the transition to ethanol-based acetaldehyde was anticipated and rationalized.

The availability of low-cost acetaldehyde opened up further opportunities. Acetaldehyde can be oxidized to yield acetic acid and acetic anhydride. (Acetic anhydride was in particular demand for the manufacture of acetate rayon, one of the early silk-like synthetic fibers.) Acetaldehyde also can be reacted with itself

(the aldol condensation) to yield crotonaldehyde. (Niacet also made crotonaldehyde this way.) Crotonaldehyde in turn can be hydrogenated to make butyraldehyde and then butanol. Butyraldehyde can be condensed in an aldol reaction and then hydrogenated to yield ethylhexanol. A whole daisy chain of products emerges. However, all of these materials have substantial and wide-ranging applications and form the heart of the petrochemicals industry. They represent the construction of useful complex organic molecules from the basic building blocks of ethylene and propylene, which in turn derive from petroleum fractions. And they were all in the scheme of things at South Charleston.

Niagara Falls Plant (Niacet)

A joint venture, called Niacet Chemicals Corporation, built a plant at Niagara Falls in the late 1920s to make organic chemicals from acetylene. The joint venture was formed in 1925 by Carbide and Carbon Chemicals Corporation, the Canadian Electro Products Company, Ltd., (a subsidiary of Shawinigan Water and Power Corporation) and Perth Amboy Chemical Works (which was later acquired by du Pont). Each of the partners brought processes and patents to the venture. The plant, which went into production in 1928, initially made acetaldehyde, acetaldol, paraldehyde, crotonaldehyde, acetic acid, acetic anhydride, and vinyl acetate. Later it made metal salts. The entire venture was bought out by Union Carbide in 1945. It was eventually sold as a specialty chemicals company in 1978.

Methanol

Synthetic methanol was first manufactured in 1930 at Niagara Falls, not at the Niacet Plant but adjacent to the Electro Metallurgical Plant there. Prior to that time, methanol—also known as wood alcohol—was produced by the destructive distillation of wood chips. Methanol is made synthetically by first reforming methane, carbon dioxide, and steam to produce synthesis gas, a mixture of carbon monoxide and hydrogen, and then reacting these materials catalytically at high pressure (1000 psi) to yield methanol. The first plant was located in Niagara Falls to use the Electro Metallurgical off-gases, which contained carbon monoxide and



Figure XIII
Niagara Falls (Niacet) Plant in 1962

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hydrogen. A second methanol unit was built in 1940 at South Charleston near the No. 3 Olefins Unit. Methanol is used as a solvent and as a raw material for making formaldehyde, an ingredient in phenolic resins. Methanol was also used in the 1930s and 1940s as a low-cost anti-freeze in automobiles. It tended to "boil off" from radiators and had to be replenished periodically, but it cost only $0.20 a quart compared to PRESTONE'S $4.50 a gallon. PRESTONE was the premium product, however, and its usage grew except for the years 1932 and 1933, which were the depths of the depression. (The economic depression was world wide and lasted from 1929 to 1939.)

Vinyl Chloride and *VINYLITE* Resins

Union Carbide was the first company to commercially produce vinyl chloride monomer (1929) and vinyl resin (1931). This came about as a result of the accumulation of ethylene dichloride that was being produced as a byproduct in the manufacture of ethylene chlorhydrin. Some ethylene dichloride was used as a dry cleaning fluid, some was used as a scavenger for tetraethyl lead in gasoline, and some was converted to ethylene glycol, but not economically. However, much was not used, and seventeen million pounds had accumulated by 1932. Ergo, a determined effort was put forth in the late 1920s to find a use for the byproduct ethylene dichloride. The use that developed was the manufacture of vinyl chloride, the basic molecule of the vinyl resins business. Thus, finding a useful disposition for an unwanted byproduct yielded a whole new industry (and to the extent that ethylene dichloride had to be made purposefully).

Ethylene dichloride was reacted with potassium hydroxide to yield vinyl chloride. Vinyl chloride, in turn, was polymerized to yield vinyl resins, which Union Carbide trade named VINYLITE. The vinyl resins process was invented in the late 1920s and patented by Dr. Ernest W. Reid in 1933. A vinyl chloride monomer unit was started up in 1929 at South Charleston and represented the first commercial production of vinyl chloride in the United States. In later years, after 1941, ethylene dichloride was cracked in a furnace to yield vinyl chloride directly. The byproduct hydrogen chloride from that process was reacted with acetylene to produce more vinyl chloride and thereby balance the whole operation out.

Straight vinyl chloride resin is brittle and stiff. However, during his student days in Germany, Dr. Curme had observed a similar product, vinyl acetate resin,

that was very soft, too soft by itself for normal use. He suggested blending the hard vinyl chloride resin with the soft vinyl acetate resin. Instead, vinyl acetate and vinyl chloride resins were copolymerized rather than blended, and the result was a product that was both strong and pliable. The proportions of vinyl chloride to vinyl acetate were in the range of six to one and seven to one. The product and variations thereof were the ubiquitous vinyl resins that have been used for car seats, wire insulation, shower curtains, molded products, fibers, phonograph records, can linings for foods and beverages, and so on and on.

A number of polymerization processes were developed for making vinyl resins including the Solvent Process, the Non-Solvent Process, the Emulsion Process, and the Suspension Process. Vinyl acetate for use in VINYLITE resins was made by reacting acetic acid with acetylene. Initially, it was obtained from Niacet in Niagara Falls, but later it was made in house. The first vinyl resins pilot unit was built in 1930 for process development and sales development. The first large scale commercial VINYLITE unit was built at South Charleston in 1935 and started up in 1936.

Polyvinyl Butyral

In parallel with the development of vinyl resins, Union Carbide developed a polyvinyl acetyl resin, polyvinyl butyral, in the early 1930s. Polyvinyl butyral is the plastic inner layer of modern automobile safety glass. Safety glass is a "sandwich" that is composed of two outer layers of glass and an inner layer of a sheet of tough "springy" plastic. The plastic binds the two glass layers together and keeps the glass from shattering. Safety glass had been introduced in 1922 and consisted then of a "sandwich" of two glass sheets and an inner layer of cellulose acetate (CELLULOID). However, this combination was too rigid (people were injured when they were thrown against it) and it discolored in sunlight. The polyvinyl butyral system, which included Union Carbide's plasticizer FLEXOL 3GH (triglycol dihexoate), overcame those problems. (A plasticizer is a liquid with low volatility that is blended with the resin to modify its properties, in this case, to make it more flexible.) The system was developed by Union Carbide at the Mellon Institute in cooperation with the Pittsburgh Plate Glass Company and patented by Union Carbide. The polyvinyl butyral resin was called VINYLITE X. However, there were some conflicting claims in conjunction with the overall safety glass program, and

as a result, it ended up as a cooperative effort with a number of claimants and sponsors, including Union Carbide, Pittsburgh Plate Glass, du Pont, Monsanto, and Libby-Owens-Ford. The new safety glass was incorporated in 1939 model automobiles and continues to be used to this day. Union Carbide licensed the process, both domestically and overseas, and received income from it for many years. Carbide also was the sole supplier of the plasticizer, FLEXOL 3GH. (Monsanto had developed an underwater extrusion method for the resin.)

Plasticizers

Union Carbide's experience with plasticizing VINYLITE X showed that there were opportunities in this area. (The earliest common plasticizer was glycerine, which was used in CELLULOID.) Accordingly, the Company developed a line of plasticizers for vinyl resins. This permitted the use of straight vinyl chloride polymers. The plasticizer was incorporated by compounding; about thirty percent of the weight of the finished resin was plasticizer. Union Carbide plasticizers were put on the market in 1938 under the trade name FLEXOL. The most widely used is FLEXOL DOP (dioctylphthalate) which is made from ethylhexanol and phthalic anhydride. A host of others were developed for special situations. B. F. Goodrich was also an early and major player in the development of plasticizers.

Amines

There are two basic lines of amine products developed by Union Carbide: ethanolamines and ethyleneamines. Both are major product groups. Ethanolamines are organic compounds with a basic nature (that is, non-acidic.) They are used directly in acid gas scrubbing and as intermediates for making detergents and shampoos. Ethyleneamines are reactive intermediates used in a wide variety of applications. A major use is for curing epoxy resins.

Ethanol amines are made from ammonia and ethylene oxide. The process was developed at the Mellon Institute in the 1920s. Three co-products are produced: Monoethanolamine, diethanolamine, and triethanolamine. The first commercial production, of triethanolamine, was in 1928 at the South Charleston Plant. The initial output was sold to du Pont for use in the manufacture of vat dyes. Manufacture of monoethanolamine and diethanolamine for sale began in 1932.

Ethyleneamines are made from ammonia and ethylene dichloride. They were first produced commercially in 1935 at the South Charleston Plant. Three principal co-products are formed: ethylenediamine, diethylenetriamine, and triethylenetetramine. The amines are called "ay-means" and not "uh-means" in the plants.

Fine Chemicals

Early research and development for chemicals was done at the South Charleston Plant in a four-building complex called the "Quadrangle." This small complex consisted of a Works Laboratory, a Research Laboratory, a Development Laboratory, and a building set up so that pilot-scale reactors and stills were available to study processes for engineering design and for the production of small quantities of materials for customer evaluation. However, demands for making new chemicals soon outstripped the capacity of that facility, and a new and larger facility was built on Blaine Island in 1937 that was called the Fine Chemicals Unit. It was used for both piloting new products and processes and for supplying small quantities of material for market development and for sale. Over time the unit grew, and eventually it could carry out both batch and continuous operations such as reaction, distillation, extraction, absorption, crystallization, filtration, centrifugation, flaking, grinding, etc. Vessels ranged in size from 50 gallons to 6000 gallons capacity and could operate at pressures ranging from full vacuum to 2000 psi and temperatures ranging from -20°C to 350°C. Chemical conversion options included oxidation, hydrogenation, hydration, dehydration, amination, condensation, polymerization, ethoxylation, etc. All-in-all it was a very versatile facility and by 1960 was producing over 30 million pounds per year of 200 different organic chemicals. About 15 technical people and 100 non-technical people were involved in the operations. It takes a special kind of person to conduct the operations—they need to be part engineer and part fine French chef. The demand for fine chemicals eventually outstripped the Unit at South Charleston, and in the 1950s a second facility, the Allethrin Unit at Institute, was adapted to making fine chemicals.

Credit Department

The Credit Department was responsible for some of the early success in chemicals. They took an active and positive role in assessing the risk of new customers and in granting credit, especially where the customer was struggling, but represented good character and good potential. Extensive credit reports were not routinely available in those days and the Credit Department got out into the field with the customers to make their own judgements. At times they counseled the customer on his financial problems and went to bat for him with other creditors. In this way they were able to further sales in every possible way. The efforts paid off and many startup companies became loyal, substantial customers.

First *KIRKPATRICK AWARD*

In 1933, Carbide and Carbon Chemicals Corporation received the prestigious KIRKPATRICK CHEMICAL AND METALLURGICAL ENGINEERING AWARD for its premier role in establishing the synthetic aliphatic chemicals industry. (Dr. Curme preferred the term "synthetic aliphatic chemicals" to petrochemicals. He felt that it was more definitive and that petrochemicals meant simply "rock chemicals" and was inappropriate. Nonetheless, the shorter term stuck in true American fashion.) This was the first time that this biennial award was made and the first of eight of these awards that the Company would receive, along with thirteen honorable mentions.

Whiting Plant

In 1930, consideration had been given to building a new chemicals plant—the Company's second—at Shawinigan Falls, in the province of Quebec in Canada. However, this course was not pursued, and instead, a new plant was planned for Whiting, Indiana near Chicago, Illinois. The Whiting Plant location came about from its proximity to the huge Standard Oil of Indiana (Amoco) Refinery located there. The new plant was to use refinery off-gases as the feed stock for the Olefin Unit and produce, initially, isopropanol, acetone, and ethanol.

Amoco had the refinery off-gases available—they were burning them under boilers—and were not particularly interested in moving downstream into chemi-

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cals, contrary to most oil companies. Also, Cornelius Kingsley Garrison Billings, the Chairman of the Board of Union Carbide and Carbon Corporation, and Robert E. Wilson, Chairman of the Board of Standard Oil of Indiana, knew each other, both with roots in Chicago, and their acquaintance facilitated negotiations. As a result, Union Carbide and Amoco reached a long-term (15 years) agreement for Amoco to provide the feedstocks for the new chemical plant. Further, Amoco had a sulfuric acid unit in its plant and would provide Union Carbide with strong acid for the ethanol process and take back and reconcentrate the weak acid generated.

Construction of the Whiting Plant began in April of 1934, and within a year, on February 14, 1935, the first pound of acetone was shipped. All of the isopropanol was converted to acetone and none was sold. The first shipment of ethanol was made in May of 1935. The plant was built with in-house construction forces, but encountered a fair amount of trouble from labor unions in the area because the in-house construction force was open shop. The experience caused the Company to reevaluate its policy, and this was the last chemical facility built with in-house forces outside of West Virginia. (The Company built facilities with in-house forces in West Virginia into the 1980s.) The Whiting Plant was the first Union Carbide Chemicals operation whose hourly work force was unionized, in this case by the predecessor of the Oil, Chemical, and Atomic Workers union (OCAW).

An acetic anhydride unit was added to the Whiting Plant in 1936 and began operating in March of 1937. The nominal capacity of the Olefins Unit was 2,500,000 cubic feet per day of ethylene, or the equivalent of 62½ million pounds per year, the same as at South Charleston. The Whiting Plant was an instant success and a moneymaker throughout its life. H. D. (Sox) Kinsey, a legendary figure in Union Carbide operations, was the first Superintendent (Plant Manager).

Ethylene Oxide

A major technology development took place in 1935. The Company developed a new, cyclic process for the manufacture of ethylene oxide by the air oxidation of ethylene. This new process gave Union Carbide a distinct technical and economic advantage over other producers of ethylene oxide up through the early 1950s. The process was based on a discovery in 1931 by T. E. Le Fort in France that silver would catalyze the reaction of ethylene with oxygen to yield ethylene oxide directly. The Company had been following Le Fort's work and procured his



Figure XIV
Whiting Plant in 1962

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patent in 1935. (Le Fort's patent covered only the use of a silver catalyst and not the process, which Union Carbide invented and developed.) The new process eliminated the consumption of chlorine, needed in the chlorhydrin process, and substantially reduced the cost of manufacture. A new unit based on the new process was installed at South Charleston in 1937. All ethylene oxide units today, both at Union Carbide and elsewhere, are based on this process. (The newer units use oxygen in place of air as a reactant to improve efficiencies.) Union Carbide had already developed a process to make ethylene glycol directly from ethylene oxide and the two processes complemented each other perfectly. (Ethylene glycol earlier had been made directly from ethylene chlorhydrin.) Many people contributed to the development of the new ethylene oxide process, but the lead role is credited to Dr. George H. Law of the Research and Development Department. Patent coverage for the process was limited and secrecy was relied upon heavily to protect the technology, which turned out to be a mistake in retrospect.

Further Growth

Another Olefins Unit was added at South Charleston in 1936-1937 to meet growing demands. The new unit had a nominal capacity of 200 million pounds per year. It was up and running in early 1938. The unit, which was called No. 3 Olefins, would be the last olefins unit built at the South Charleston Plant. It operated well for thirty years, and it was shut down when the natural gas streams in West Viginia declined and no replacement feedstocks were available.

BAKELITE and the Bound Brook Plant

On November 21, 1939, Union Carbide acquired the Bakelite Corporation in exchange for 187,500 shares of stock. Bakelite made and sold thermosetting phenol-formaldehyde resins and urea-formaldehyde resins. It also made and sold thermoplastic cellulose acetate and polystyrene resins. All were sold under the trade name BAKELITE. The product lines were regarded as a good complement to the vinyl resins that Union Carbide made, and it enhanced the Company's presence in the plastics business. In addition, Bakelite provided a captive outlet for a number of Union Carbide products, notably methanol, which was used to make formaldehyde. Phenol for the operation was purchased at the time.

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The Bakelite Corporation had its roots in the General Bakelite Company, which was formed in 1910 by Dr. Leo Hendrik Baekeland. Baekeland, a native of Belgium, was a wealthy and prolific inventor—he had some 400 patents to his name over his lifetime. He had already made a fortune by inventing VELUX photographic paper, which he had sold to George Eastman and which formed the basis for the start of the Eastman Kodak Company. The trade name, BAKELITE, was obviously coined from his name and it had good recognition and a high reputation in the market place. Professor Baekeland was a real forerunner; he was obsessed with the quality of his products and their end uses and required his customers to become qualified before selling to them.

The Bakelite Corporation had come about from a merger in 1922 of General Bakelite, the Condensite Company, and the Redmanol Chemical Company. These three companies had conflicting patent claims, and the merger resolved the problem. The incentive for selling the Bakelite Company to Union Carbide came about, in part, because Dr. Baekeland was getting on in years (he died in 1944 at the age of 80) and his son, George, was not interested in running the business.

Dr. Baekeland had started making phenolic resins at Perth Amboy, in New Jersey. As the business grew, he moved it in 1932 to new and larger quarters at Bound Brook, New Jersey, which is the site of the present day Bound Brook Plant. Bakelite also had research facilities at Bloomfield, New Jersey, which was where Dr. Baekeland lived. The research facilities were included in the deal. However, they were closed and a new Research and Development center was built at Bound Brook in the early 1950s.

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Figure XV
Bound Brook Plant in 1940

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Texas City Plant

By the late 1930s the economy was improving rapidly, in part due to preparations for the war that was brewing in Europe. Demand for the Company's products was up and another new plant was needed. The site picked for the new plant was Texas City, Texas, near Galveston. The choice of site was dictated largely by the raw materials needed. The Texas Gulf Coast was booming with oil refineries, and refinery off gas had become the feedstock of choice based on cost and availability. A subsidiary of Standard Oil of Indiana, the Pan American Refinery at Texas City, had the requisite materials—both refinery off-gas and fuel gas. Based on Union Carbide's and Standard of Indiana's mutually beneficial arrangements at Whiting, Indiana, and the fact that Standard of Indiana still had no plans to move into the chemicals business, an agreement was reached in 1938 to sell these materials to Union Carbide. The deal was struck by H. Earle Thompson of Union Carbide and Robert E. Wilson, Chairman of the Board of Standard of Indiana.

Design work was started on the Texas City Plant in 1939 and construction proceeded through 1940. Included were an Olefins Unit, an Ethanol Unit, an Isopropanol Unit, and Ethylene Oxide Unit, and an Ethylene Glycol Unit. The plant started up in May of 1941. Harley Ross, from the South Charleston Plant, was the first plant manager. The initial capacity of the Olefins Unit was to be 66 million pounds per year of ethylene, but was increased to 100 million pounds per year before construction started. The capacity of the plant was increased incrementally to 200 million pounds per year in 1944-1945 and ultimately produced ethylene at rates approaching 300 million pounds per year.

The Texas City Plant was the first chemicals plant built by an "outside" construction contractor, in this case Ford, Bacon, and Davis. All of the engineering, however, was done in-house at South Charleston. The Ethanol Unit at Texas City was the first unit in which all of the heat exchangers were designed in-house. Previously, heat exchangers had been designed by equipment manufacturers against performance specifications. Often, however, the actual performance of the heat exchangers was unreliable and resulted in bottlenecks in plant operations. In troubleshooting plant problems, Charles H. Gilmour, a pioneer technologist, developed designs for heat exchangers and design methods that assured reliable, efficient, and predictable performance. These methods were applied successfully to the Ethanol Unit and then to all other new designs. They became standards in the Company

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and in the industry. Another pioneering engineering technologist, Dr. Donald S. Ullock, made centrifugal pumps reliable for chemical plant service. He did this by determining that shaft deflection was a critical factor in pump operation and by establishing design parameters to limit deflection. His work on pump shafts and bearings also set standards for the industry.

The Texas City Plant was to grow to be one of the largest chemical complexes in Union Carbide. It later included facilities for the manufacture of vinyl monomers and vinyl resins oxo alcohols, and high pressure polyethylene resins. The plant's hourly work force was unionized by the Galveston Metal Trades Council in 1944. There was a difficult strike in 1949—the first in which the managerial and technical staff operated the plant for an extended period. Generally, labor relations have been good since then.

The plant was connected by pipelines to a barge and ship terminal several miles away. Products could move on Company barges via the intracoastal waterway to the Mississippi River and then up the Ohio and Kanawha Rivers to South Charleston. Products could also move by ship to a terminal at Carteret, New Jersey, to serve East Coast markets. (One of the chemical tankers Union Carbide owned was the S.S. R. E. Wilson, purchased from Standard of Indiana.)

In 1941, the first ethylene plant outside Union Carbide was built. It was designed and constructed by Stone and Webster for the Dow Chemical Company at Freeport, Texas. Monsanto also built an olefins unit at Texas City at about the same time. (Union Carbide was called in by the War Production Board early in the World War II to get the Monsanto plant straightened out. Harley Ross was instructed by H. Earle Thompson to help them get their plant running but to "tell them nothing.")

Research & Development and Engineering

Research and Development in Carbide and Carbon Chemicals Corporation had its roots in the work of the Mellon Institute before the parent company was organized. Originally, Research and Development were two separate functions, organized separately. The interface between the two was not always distinct, but, largely, Research was about inventing, basically seeking new petrochemicals that could find substantial markets, and Development was about reducing inventions to practice. There had been no models to go on, so the functions evolved as needed.

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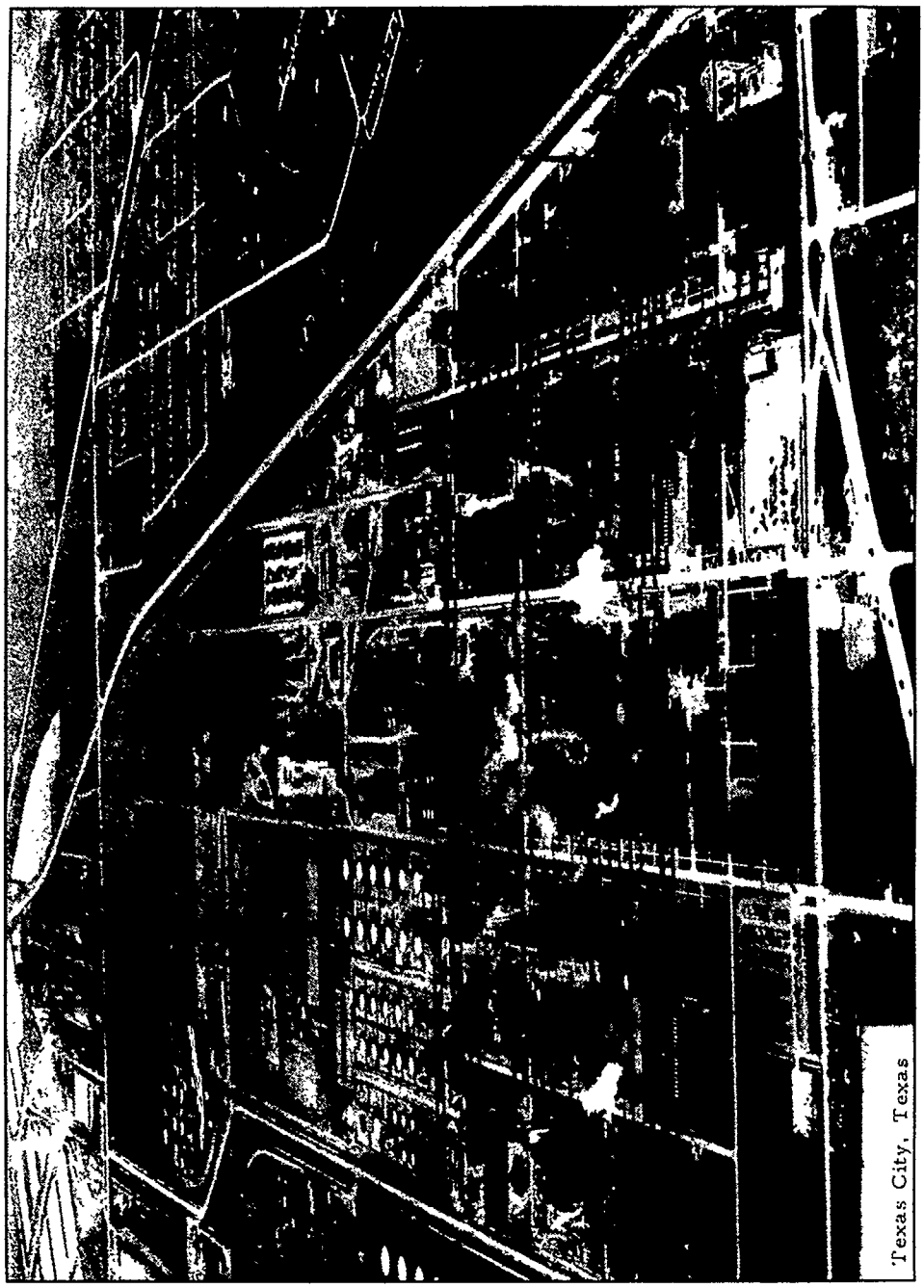


Figure XVI
Texas City Plant in 1962

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Research tended to be tied more closely to the marketplace and Development to the plants. The Mellon Institute also remained in the picture for many years, first as a sales development laboratory and later doing specialized work in toxicology and health. The picture was complicated by the fact that development work was also done by the plants and by the engineering organizations that were process oriented. This was especially true of development in the olefins units. Clendenin, itself, had been mostly a development effort.

There was an early attempt, in 1922, to centralize Research for the entire Corporation in laboratories at Long Island City near New York. However, this did not last long. The Research function for chemicals was shifted to the South Charleston Plant, which is where the action was, shortly after the plant was established. The management was separated under Dr. G. H. Reid, who was the technology manager, and H. C. Holden, who was the administrative manager. They were functionally under the plant manager, but Dr. Curme remained the Chief Chemist in New York and provided overall technical direction. (He was made Vice President and a Director of Carbide and Carbon Chemicals Corporation in 1929.) However, Dr. Franklin Johnston recalls that the organization was so informal that it was hard to tell who was in charge.

Engineering had been a separate, internal activity from the outset, owing to the constantly growing need for plant design and construction. The engineering function was headed for over thirty years by H. Earle Thompson, who had signed on from the Linde organization in 1920 for modifying the Clendenin Plant. There were two basic parts to engineering: process engineering and design and construction. In-house engineering was an essential function inasmuch as no contract engineering services existed at that time with the technology and skills to do the needed work. Furthermore, there was a strong desire not to disseminate the Company's technology through outside contracting—an attitude that persisted into the 1950s. (Early plants were built inside buildings and when the shift was made to open structures at the Whiting Plant, H. E. Thompson decreed that henceforth the tops of all distillation columns in chemicals units should be at the same level to discourage interpretation of the process from outside the plant—the levels of the still bases varied, of course).

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Products and Services — 1940

Starting with half a dozen organic chemicals in 1925, the Chemicals Company was marketing 157 chemical compounds by 1940. Of the 157: 19 were developed by the Company as entirely new products never made before; 96 were known only as laboratory items and were first produced commercially by the Company; eight were first produced commercially by a synthetic method; and five were first produced by a new and more economic method than had been known. A product list from the annual report from 1940 for the whole Corporation is shown in the Appendix.

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Chapter Three
THE WAR YEARS (1940 - 1945)

The Second World War put a great burden on all industry to produce goods for the war effort at record levels in spite of shortages of resources and people. Union Carbide was no exception. Indeed, the South Charleston Plant was awarded the coveted Navy "E" award in September of 1942 for its outstanding performance. However, the Company also was asked to take on a number of extraordinary tasks beyond its normal activities.

Synthetic Rubber Program

The first of these tasks was a crash project for the production of butadiene and styrene for the manufacture of synthetic rubber. In the course of several weeks at the outset of the war in the Pacific, Japanese armies had overrun the rubber plantations in Southeast Asia. The United States got ninety percent of its rubber from that area at the time, and while it had stockpiled rubber in anticipation of increased needs, it wasn't prepared to lose nearly its entire source of supply.

To remedy the situation, the U. S. Government's Rubber Reserve Program embarked on an emergency effort under Bernard Baruch to establish a synthetic rubber industry modeled on Germany's Buna-S rubber technology. The Baruch Committee said:

> "Of all the critical and strategic materials, rubber is the greatest threat to our Nation and to the Allied cause. Production of steel, copper, aluminum, alloys, or aviation gasoline may be inadequate to prosecute the war as rapidly and effectively as we would wish, but at worst we still are assured of sufficient of these items to operate our armed forces on a very powerful scale. But if we fail to secure quickly a large new rubber supply our war effort and our domestic economy both will collapse. Thus the rubber situation gives rise to our most critical problem."

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As a result, the synthetic rubber program had the highest wartime priority of any industrial program in the country.

Union Carbide was given the task of designing and building plants and producing butadiene and styrene, the principal ingredients of Buna-S rubber. Styrene had been produced commercially at the time, but butadiene was made in small quantities only as a byproduct of olefins operations and refinery operations. Union Carbide was already the major producer of butadiene in the country. Since mid-1941, at the request of the Government, Carbide had been recovering five million pounds per year of butadiene as byproducts of the South Charleston and Whiting olefins operations.

Within a period of fourteen months, from December 1941 to January 1943, Union Carbide devised a process to make butadiene from fermentation alcohol, designed the plant, built it and started operations. The styrene plant, based on a Union Carbide process, was similarly designed and built. It started up in June of 1943. The Union Carbide styrene process began with ethylene and benzene and involved the dehydration of methyl phenyl carbonyl to avoid the difficult separation of ethylbenzene and styrene. Some of the alcohol feedstocks for the butadiene unit were actually whiskey from Kentucky distilleries. The butadiene process was not economic by ordinary standards, but in light of the shortage of rubber, cost was not a factor. The Federal Government paid the bills and owned the plants.

The first butadiene plant was built on the Kanawha River at Institute, West Virginia on the site of Charleston's airport—the only reasonably flat ground nearby. The B. F. Goodrich Company built a rubber plant on the same site to take the output and convert it to raw synthetic rubber, called GR-S for Government Rubber-Styrene. Another butadiene plant was built by Union Carbide at Louisville, Kentucky. A third plant was built to the Union Carbide design by the Koppers Company at Beaver Falls, Pennsylvania. The output of these plants yielded feedstocks to produce sixty-three percent of the Country's rubber by 1944. An interesting sidelight is that the structural steel for the pipe racks in the Institute Plant came from the Second Avenue "El" in New York City, which was being demolished at the time. It's still in the plant. (The "El" was an elevated railway that ran along and over Second Avenue and served the same purpose as a subway.)



Figure XVII
Institute Plant in 1962

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When the war was over, the plants were shut down. Union Carbide bought the plant at Institute and converted it to the manufacture of other petrochemical products. (Charleston had to find a new airport. It built one nearer to the city by cutting off the tops of three hills and filling in between them. The result was spectacular, if somewhat disconcerting, for arriving travelers. However, the airport has an excellent safety record despite the general impression that it is hazardous.)

Manhattan Project

The second task that Union Carbide was asked to undertake during the war was participation in the "Manhattan Project," the atomic bomb program. The scope of the Company's participation included: research and engineering on the gaseous diffusion process to separate uranium isotopes, locating and processing uranium ores and other materials (some from Union Carbide's vanadium mine tailings in Colorado), providing especially pure carbon and graphite for nuclear reactors, and contributing to the design and operating the K-25 gaseous diffusion plant at Oak Ridge.

The K-25 gaseous diffusion project staggers the imagination from the standpoints of both scope and technical challenge. The problems were largely chemistry and engineering rather than physics. The objective was to separate the fissionable uranium 235 isotope (U-235) from the non-fissionable uranium 238 isotope (U-238). Uranium 235 occurs in nature at a concentration of about 0.7 percent in uranium 238. It has to be concentrated to over 90 percent to be efficient in a bomb. Because the two isotopes are chemically identical, a physical means of separation was required. In the course of three years, starting in 1942, schemes were devised to convert the uranium oxide ore to gaseous uranium hexafluoride so it could be processed, a porous nickel barrier developed and manufactured through which the lighter isotope (U-235) would diffuse more quickly than the heavier isotope (U-238), equipment developed to do this, and a plant built and operated. Maybe this doesn't sound like too much until you consider that there were three thousand five hundred stages required in the separation process, that there were thousands of interstage compressors and coolers, that the plant had to be designed before the barrier development was completed, that the system operated under vacuum and any leakage into the system was intolerable, that suitable seals to meet the near impossible leakage criterion had to be developed and manufactured, and that ura-

nium hexafluoride is a corrosive gas and corrosion in the system was also intolerable—especially in the micropore barriers. Furthermore, the system had to operate efficiently and reliably, because it couldn't readily be opened up once operation had begun inasmuch as the material being processed was corrosive and radioactive. The magnitude of the operation is indicated by the fact that it required three percent of the electric power in the United States. Twenty two thousand people were required for the construction of the facility, and 12,000 people were required to operate it—most of them women.

Development of the porous nickel diffusion barrier, the heart of the process, began in early 1942 at Columbia University under Dr. Harold Urey, a Nobel laureate. Drs. Edward Norris and Edward Adler of Columbia initiated the work, based on a concept put forth in Germany in the 1920s, and Union Carbide joined the effort in the fall of 1942. However, Norris and Adler's work stalled out in early 1943 and Union Carbide took over the responsibility for development of the barrier. The work was successfully completed by Frasier Groff of the Bakelite Company and by Clarence Johnson of Kellex (a subsidiary of the M. W. Kellogg Company). These two provided the breakthroughs and the development that made the diffusers possible. Groff was a brilliant eccentric who relentlesly pursued his objectives to the exclusion of all else—and expected others to do the same. He was a chemist from Bound Brook with a background in plastics processing that he successfully adapted to the development of the nickel diffuser. Each diffuser was a 5/8 inch diameter by eight feet long sintered nickel tube rolled from sheets. The pores were only ten times the diameter of the uranium hexafluoride molecules that diffused through them, and the total diffuser area needed was measured by the hundreds of acres.

Houdaille-Hershey fabricated the barriers and the enclosing assemblies were made by the Chrysler Corporation. The entire system, equipment and piping, had to be nickel plated for corrosion proofing. (To make the entire system out of nickel, the material needed to handle uranaium hexafluoride, would have taken the world's total supply of nickel!) Compressors and seals were developed and made by the Allis-Chalmers Company, and were regarded as the greatest mechanical engineering feat on the project. Special valves were made by the Crane Company. Engineering design services for the plant were provided by Kellex with review and approval by Union Carbide. Construction was done by the J. A. Jones Company. Union Carbide operated the plant.

The K-25 plant, in concert with the Y-12 electromagnetic separation plant, produced the enriched uranium used in the first atomic bomb. (The test piece that was set off in New Mexico and the second atomic bomb were plutonium bombs.) The bombs, of course, ended the war in the Pacific. The quality of the work done at Oak Ridge is indicated by the fact that the gaseous diffusion plant operated successfully for over twenty years without interruption or shutdown!

There were three major parts to Oak Ridge. One part was the K-25 gaseous diffusion plant, a production unit for enriched (U-235) uranium. The second part was the Y-12 electromagnetic separation plant. It was another production unit for enriched (U-235) uranium and consisted of a series of gigantic mass spectrometers, called "calutrons". Y-12 was designed by Tennessee Eastman and built by Stone and Webster. The Federal Government had hedged its bets by building plants based on different processing technologies. The Y-12 plant operated in series with the K-25 plant in the beginning. It was eventually replaced by the K-25 plant for enriching uranium and converted to uranium fabrication and other supporting services. The third part of Oak Ridge was what was called the Clinton Laboratories, after the village of Clinton that had been near the Oak Ridge project. The Clinton Laboratories, code named X-10, and now called Oak Ridge National Laboratory (ORNL), were the scientific laboratories at the site. They included a graphite nuclear reactor for the production of plutonium for research purposes and facilities to develop processes for the separation of plutonium from uranium. It eventually became one of the great national nuclear laboratories in the United States, along with the Argonne National Laboratory near Chicago and the Los Alamos Scientific Laboratory in New Mexico. The Clinton Laboratory was managed in the early years by the Monsanto Company. It was under the technical guidance of an independent research director, Dr. Eugene Wigner, a Nobel Laureate. Later, under Union Carbide, it was managed by Dr. Alvin Weinberg, "Mr. ORNL", who more than anyone guided the institution in directions recognized as vital to society.

All of Union Carbide's efforts on the Manhattan Project were headed up by Dr. George Felbeck. Clark Center, who had been an assistant plant manager at the Union Carbide Whiting Plant, was responsible, first, for the design oversight, and then followed H. D. "Sox" Kinsey as plant manager for the operation of the gaseous diffusion plant (K-25). Later, after the war, Center was responsible for the operation of the entire Oak Ridge Complex when Union Carbide took it over. The nuclear operation was conducted for a modest annual fee at arm's length from the Company's commercial operations.



Figure XVIII
Oak Ridge K-25 Plant (1980s)

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Polyethylene

The third major task that Union Carbide was called on to handle during the Second World War was the manufacture of polyethylene, a plastic electrical insulation that was critical to the operation of radar. Radar had been invented by the British just prior to the war and radar ground stations proved invaluable in the defense of their country in the Battle of Britain. It then found much wider use as mobile units in the Royal Navy and the Air Force.

Polyethylene had been discovered by Imperial Chemical Industries (ICI) in 1933. They were doing exploratory research on high-pressure (about 25,000 psi) processes under the sponsorship of Sir Robert Robinson, and in the course of trying to make ethyl phenyl ketone from benzaldehyde and ethylene, inadvertently produced a small amount (0.4 gram) of what was later identified as polyethylene. The experimental work was done by Drs. E. W. Fawcett and R. O. Gibson, who were credited with the discovery. In several subsequent runs, they made a total of almost four grams of polyethylene. Fawcett in particular recognized the importance of the discovery because olefins were not supposed to form high molecular weight polymers. However, work was discontinued for several years owing to the economic depression. In 1935, work was started again, and this time the focus was on making polyethylene. Operating at 2000 atmospheres pressure in a stirred autoclave, Dr. Michael Perrin successfully produced eight grams of the product. The process was developed and polyethylene was produced commercially for the first time by ICI in 1938 (the application was insulation of submarine cable). In 1934, Drs. James W. Conant and P. W. Bridgeman of Harvard also patented a high-pressure process for the manufacture of polyethylene, but they did not actually make any polyethylene.

The Linde Air Products Company was aware of ICI's work and in 1940 elected to experiment with polyethylene at Tonawanda, New York, under the aegis of Dr. Corneille O. Strother, using the conditions in the Conant and Bridgeman patent. Linde already had experience with medium-high pressure equipment in separating the components of air and with very-high pressure operations in making synthetic gems. Therefore, they were a leg up on moving into the very-high pressure world. In 1941, Linde succeeded in making polyethylene by pumping ethylene through a heated tube at a pressure of about 30,000 psi with air as the catalyst. (This pressure is comparable to the breech pressure in a cannon when it

goes off.) The wall thickness of the tubular reactor was one-third of the overall diameter, very much like a gun. Liquid ethylene was pumped with what was called an "intensifier," not a compressor, inasmuch as not much compression—that is, reduction in volume—was involved. Linde experimented with pressures in the range of 25,000 psi to 50,000 psi and found that high, continuous throughputs could be obtained at the higher pressures with low levels of oxygen (air) catalyst, far below the limits of the ICI patent.

The U. S. Navy was desirous of installing radar in its ships, and early in 1942 had commissioned E. I. du Pont de Nemours and Company to build a polyethylene plant under license to ICI to serve the Navy's needs. A young Union Carbide engineer, serving in the Navy's Bureau of Ships, learned of that arrangement and was also aware of Linde's work at Tonawanda. He suggested to the Navy that they also consider Union Carbide for this work. As a result, on the strength of Linde's work at Tonawanda, Union Carbide was commissioned in August of 1942 to build a pilot plant at Tonawanda to produce material for evaluation and in December of 1942 to build a one-and-one-half-million pounds per year production unit at South Charleston, West Virginia, using Union Carbide's technology.

The larger plant was designed and built under crash conditions by Carbide and Carbon Chemicals Corporation first under the leadership of Dr. George Felbeck (before he was pulled off for the Manhattan Project) and then under Edward Shetter of Olefins Engineering. The problems were daunting. Suitable equipment was not available and had to be developed. Nonetheless, a six-reactor, six-pump plant was designed and built and was ready for service in about eight months—in April of 1943. The material produced was superior to ICI's and to du Pont's, possibly owing to the fact that Union Carbide used a lower catalyst (air) concentration and a plug-flow tubular reactor rather than the back-mixed autoclave used in the ICI process. As a result, Union Carbide supplied all of the polyethylene needed in the war for use in radar after its unit came on stream. The capacity of the unit was eight times its design rating. The U. S. Navy's Bureau of Ships stated on November 1, 1945 that:

> "Starting in April 1942, the Linde Air Products Company's division of Union Carbide and Carbon Corporation, independently commenced a development program for producing polyethylene. The first phase of the work was completed in July 1942, and cable samples were prepared from the experimental polymer being produced at the rate

of 100 pounds per day at the pilot plant located at Tonawanda, NY. Tests performed at the Naval Research Laboratory indicated a general superiority of the Linde polyethylene over either the du Pont material or the ICI material...(this) resulted in the use of the Union Carbide polyethylene almost exclusively in radio frequency (RF) cable...after Union Carbide began operation of a plant at South Charleston, West Virginia in April, 1943."

Wartime Efforts

The wartime efforts were carried out in an atmosphere of total involvement that may be hard for many people today to understand, especially in light of more recent conflicts carried out on limited bases. Essentially, the whole planet was at war in the 1940s. There wasn't a waking moment for a period of five years or so when one wasn't either involved in or acutely aware of the war. Everybody was affected one way or another—some more than others, of course. The outcome of the war was not assured until the final year, and the ultimate concern was survival. The attitudes and extraordinary efforts of the war years need to be understood in that light. Not everyone was a hero, but most people did their part and many people did more. It is interesting to note that Union Carbide's earnings were flat for the entire period (1940-1945) despite operating at full capacity for the entire period—no special advantage was taken by the Company of the war situation.

Perhaps two other special wartime efforts deserve mention. The first was the provision of synthetic gems by Linde for instrument bearings for navigational equipment—an outgrowth of John Motley Morehead's work. The second was the provision of proximity fuses—the devices used to set off shells when they neared a target. National Carbon developed these and a rugged alkaline battery to power them; these EVEREADY alkaline batteries were later put on the civilian market (and the ENERGIZER Bunny was on his way).

One other interesting development occurred in 1945. Dr. Helmut W. (Hap) Schulz, of the Union Carbide Chemicals Corporation Development Department in South Charleston, conceived the idea of using intense, tunable monochromatic radiation in the infrared spectrum as a source of energy for selectively activating organic reactions (now known as laser catalysis). However, he needed a suitable source of radiation and promoted a post-doctoral fellowship in radiation physics to

explore the technology for producing such radiation. Through Dr. Schulz' efforts and on his recommendation, Union Carbide established in 1947 a series of $10,000 per year fellowships at Columbia University to explore the area under the direction of Dr. Charles H. Townes of the Physics Department. Dr. Arthur Schawlow was one of the fellows engaged to conduct the work. That work led to the invention in 1951 by Dr. Townes of the maser (Microwave Amplification by Stimulated Emission of Radiation) and the laser (Light Amplification by Stimulated Emission of Radiation). Subsequent work by Dr. Schawlow demonstrated the selective stimulation of chemical reactions by laser light. Both Professors Townes and Schawlow received Nobel Prizes for their work and have acknowledged the key roles played by Dr. Schulz and Union Carbide.

Chapter Four
GROWTH (1945-1960)

Immediately following World War II there was a surge in the American economy resulting from the pent-up demand for goods and services resulting from five years of wartime shortages and the fact that people had saved money and had it to spend. New homes and automobiles hadn't been built since 1941 and almost everybody wanted one of each (that was before the days of two of each). Furthermore, the Marshall Plan—named after General George C. Marshall who had promoted the plan as a humanitarian measure to assist in the rebuilding of war torn Europe—was stimulating recovery and demand overseas. The result, with minor setbacks from time to time, was a continuing demand and a long-term healthy economy—something that hadn't been seen since the 1920s.

The period of 1945-1960 was one of major growth for Union Carbide Corporation. Sales increased from $416 million in 1946 to $1,712 million in 1960, about $9 billion in 1997 terms. This was an average increase of about eight or nine percent per year after allowing for inflation—which amounted to only about two or three percent per year. (1946 was the first year that Union Carbide reported its sales figures.) There was also a shift in the Corporate product mix. Whereas chemicals and plastics sales had been only about 40 percent of the total in 1946, they were about 54 percent of the total in 1960. Over 200 new products were sold by the Chemicals and Plastics groups in the period 1945-1960.

Several major changes were making themselves felt in the Company's businesses in the late 1940s and in the 1950s. The first was a shift to a market orientation. Previously, goods had been made and then markets found. Now, increasingly, markets dictated their needs. The second change was the rise of competition. As demands grew, others saw opportunities and were able to enter the business, in part because the technology was coming available on the open market. Oil companies, especially, sought to move downstream into more profitable areas. Others were able to get in on a stripped down, low-cost basis without the expense of inventing a product and developing a market. One aspect of the new competition was that increasingly larger and more costly plants were being built to achieve the economies of scale. The third change was in financing. Whereas previous expan-

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sions had been financed mostly with earnings, now new construction was being financed with borrowed money. In 1945, the Company's long-term debt was essentially nothing. By 1960, long-term debt amounted to almost half a billion dollars. One reason, of course, was that there was more demand for capital than retained earnings provided. Another reason was that the cost of money was low, typical interest rates were three or four percent.

Union Carbide and Carbon Corporation had been a holding company since it was organized and stayed that way until 1949. Each of the major Companies that made up the Corporation maintained a separate identity with its own president and board of directors. Corporate policy was made by a committee that consisted of the presidents of the major companies. However, in 1949, Union Carbide and Carbon Corporation became an operating company, and the heretofore independent subsidiaries became divisions of the parent. Some of the subsidiaries were combined. The principal divisions that emerged were: Bakelite, Carbide and Carbon Chemicals, Electro Metallurgical, Linde Air Products, and National Carbon. (There were a number of other smaller units plus the overseas subsidiaries.)

The purpose of forming an operating company was to provide more direction to the divisions and to tighten controls. An operating committee was set up at the corporate level to provide the new management. In 1957, the corporate name was changed from Union Carbide and Carbon Corporation to Union Carbide Corporation and the Union Carbide hexagon was adopted as the corporate logo. The names of some of the divisions picked up the term Union Carbide to strengthen Corporate identity. The change to an operating company mode did not occur instantaneously—some contend that it took until 1962 for the new culture to become effective. A continuing problem was the intense competition for capital and for funds for Research and Development.

A major symbol of corporate identity arose in 1960 in the form of an impressive, new, 52-story corporate office building at 270 Park Avenue in New York. Company activities in New York, which had long since outgrown the original office at Madison Avenue and 42nd Street, were consolidated in the new facility. Also, in 1959, a new 600-acre Technical Center for research, development, and engineering was established at South Charleston, West Virginia, and a new customer service center and research facility was built at Tarrytown, New York.

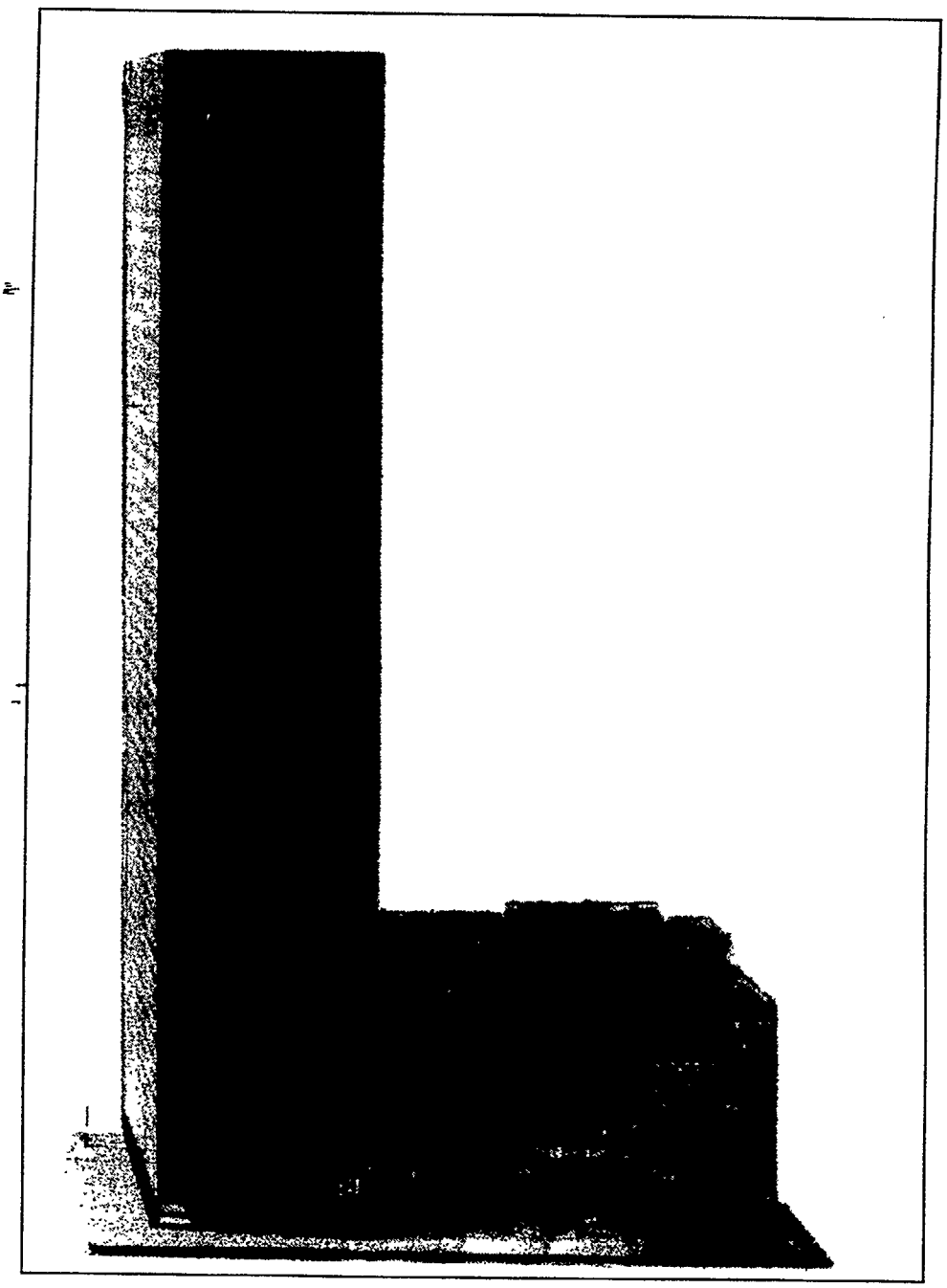


Figure XIX
Union Carbide Corporate Offices 1960 - 1980
270 Park Avenue, New York, NY

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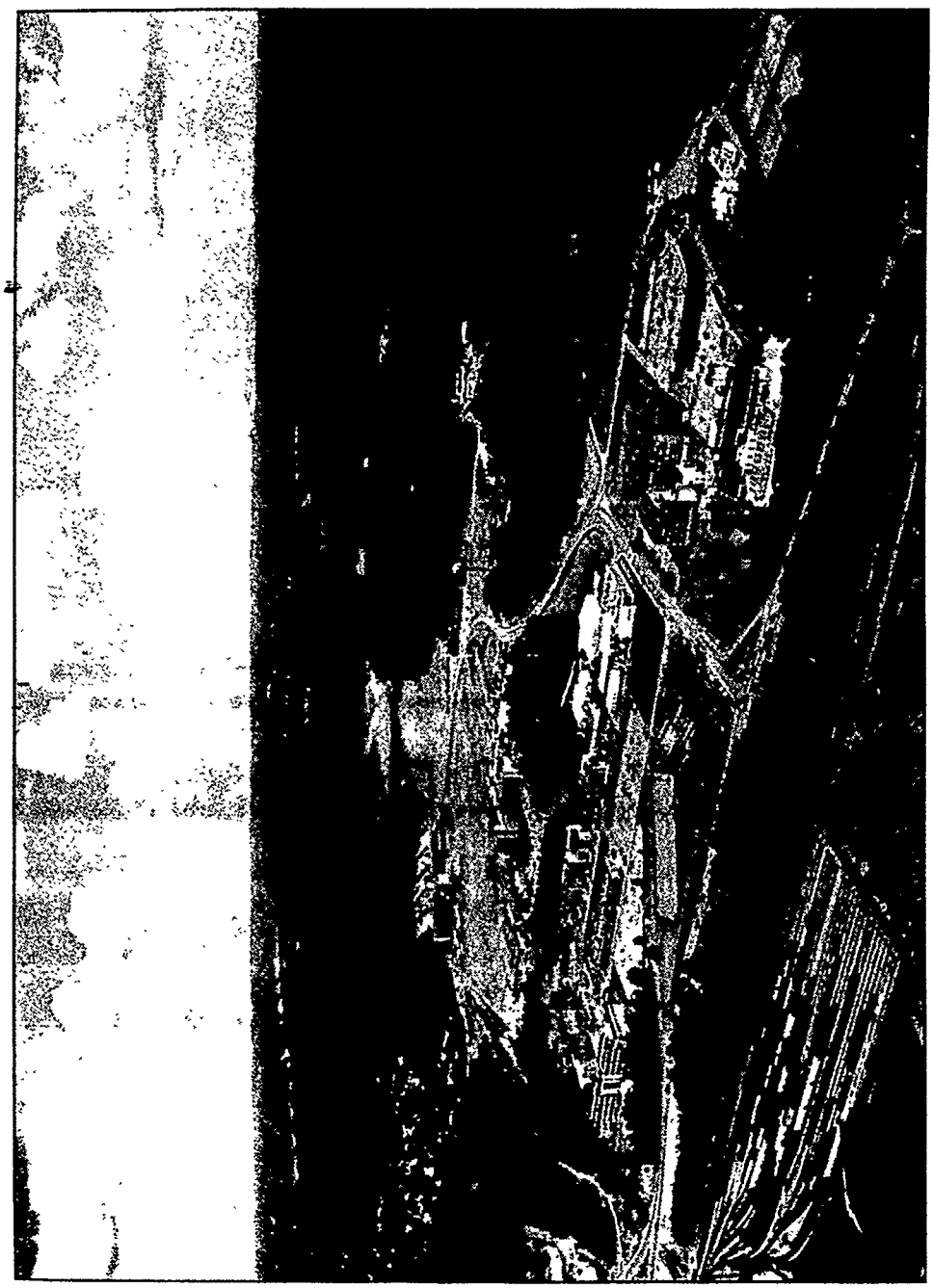


Figure XX
Union Carbide Technical Center at South Charleston, WV (1959 - Present)

The oxygen business had taken off with the advent of the oxygen-consuming Basic Oxygen Process for making steel in place of the Bessemer converter and the open hearth furnace. Added demand for oxygen also came from the use of oxygen in rockets. Linde, however, had fallen behind as competitors built dedicated oxygen units adjacent to customer's plants and delivered oxygen via pipeline across the fence (rather than delivering oxygen by tank wagons or railroad tank car from a large central system as Linde did.) Linde, however, adjusted and caught up by doing the same thing. National Carbon's battery business also had fallen behind in the 1950s as competitors came into the market with higher-quality "leakproof" batteries. After some soul searching, in which they considered getting out of the battery business, they came back with a superior product and once again were market leaders. One thing that helped in that difficult period was separating the battery business from the carbon electrode business—they were too unlike to be marketed together effectively.

Expansions and New Plants

To keep up with burgeoning demand for chemicals and plastics, major expansions were made in the years immediately after World War II to established plants at Charleston, West Virginia, Whiting, Indiana, Bound Brook, New Jersey, and Texas City, Texas. In addition, the plant at Institute, West Virginia, which had been used for the wartime rubber program, was purchased from the government in 1947 and fitted out to make an array of petrochemicals.

Major new petrochemical plants were built in 1955 at Seadrift, Texas, near Victoria; in 1956 at Torrance, California, near Los Angeles—the first petrochemical plant on the West Coast; in 1956 at Sistersville, West Virginia, on the Ohio River; and in 1960 at Brownsville, Texas. In addition, the Company purchased the Visking Corporation in 1956 with its facilities, 3000 employees, and $58 million worth of sales per year. Other expansions included a phenol plant in Marietta, Ohio in 1949, a small petrochemicals facility at Montreal, Canada, in 1956, and a small petrochemicals complex at Ponce, Puerto Rico, in 1960. (The Ponce facilities, while not strictly domestic, served mainly the U.S. market.) The base loads on the plants were mostly ethanol, isopropanol, ethylene oxide, and their derivatives plus vinyl and phenolic resins. The Sistersville Plant was devoted to silicones, and the Brownsville Plant made acetic acid and methyl ethyl ketone by a new process,

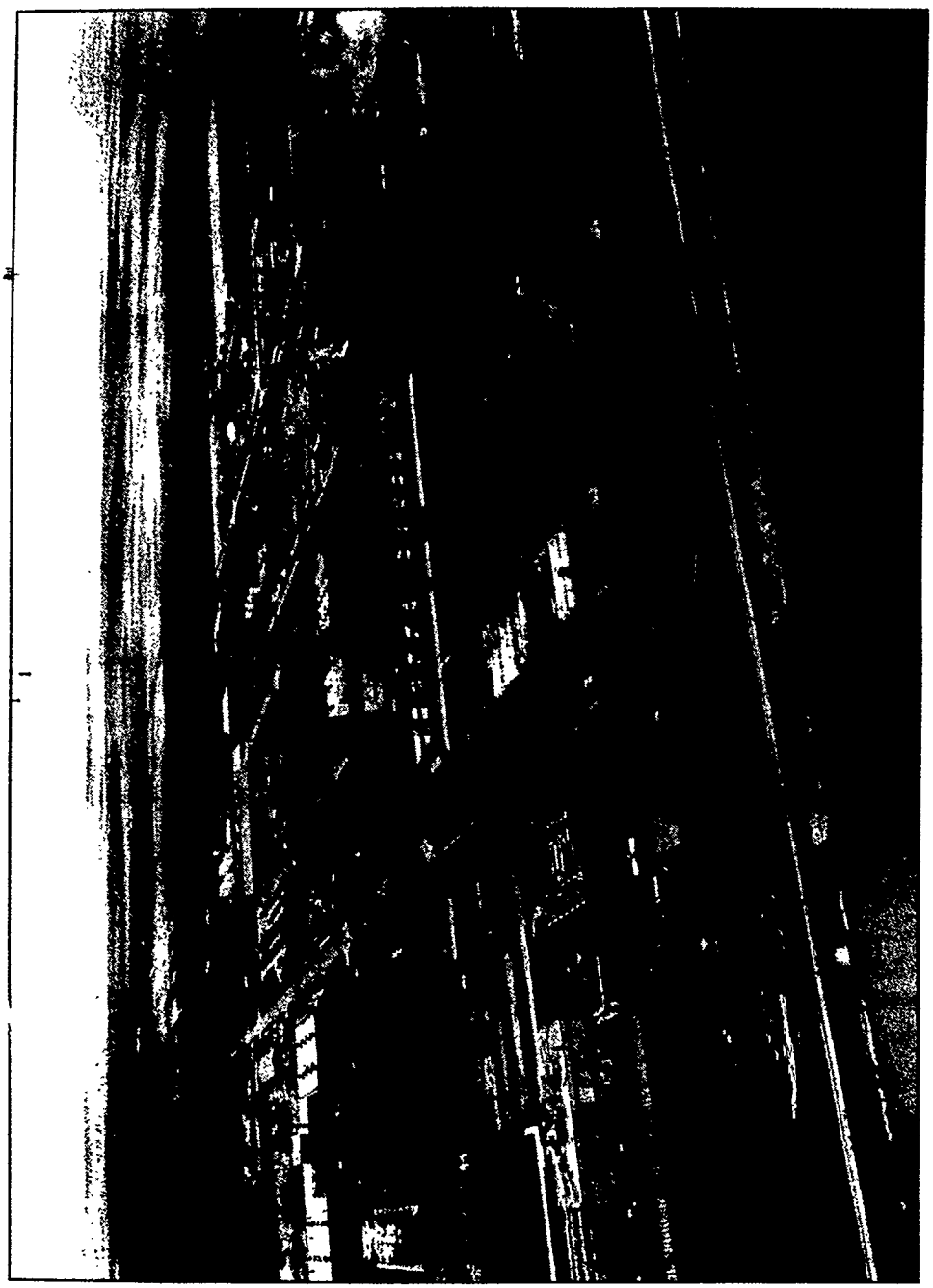


Figure XXI
Seadrift Plant in 1962



Figure XXII
Torrance Plant in 1962

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Figure XXIII
Brownsville Plant in 1962

butane oxidation. (The Brownsville plant had been built originally by Carthage Hydrocol to make gasoline from natural gas. However, the venture was not successful, and Union Carbide bought the facility at a bargain basement price to acquire the infrastructure and an operating oxygen unit.)

Polyethylene

Polyethylene, the resin of radar fame in World War II, was beginning to make waves. Initially there had been serious questions as to whether or not the Company should stay in the business, and the wartime unit at South Charleston was shut down briefly. Polyethylene was viewed by some as having limited potential, useful mostly for wire and cable insulation. Furthermore, Howard Bunn, then sales manager for plastics and later president of the Corporation, had been getting negative readings on the outlook for polyethylene. It was said, among other things, that polyethylene wasn't soluble in anything, that it couldn't be used as a coating, that it couldn't be injection molded with suitable gloss, and that conventional adhesives wouldn't stick to it. Bunn journeyed to the Bound Brook laboratories of Bakelite in late 1945 to get a reading from the people there. They were aware of his concerns and were ready. They showed him polyethylene that they had successfully embossed, laminated, printed, injection molded, and compression molded. They also gave him samples of useful articles that they had fabricated by these various methods, and noted that polyethylene had been blowmolded successfully by others. The extent to which this show influenced his thinking is not known, but the decision was made soon thereafter to proceed with the development of the polyethylene business. Polyethylene, of course, went on to be the world's most widely used thermoplastic, with Union Carbide leading the way.

The first step in getting polyethylene back on track was to buy the million-and-a-half pounds per year wartime South Charleston Unit from the U. S. Navy and start it up for process and market development. (The licensing aspects were resolved in 1952 in an anti-trust agreement between Imperial Chemical Industries and the Federal Government.) Based on an improved design, a 30 million pounds per year high-pressure polyethylene unit was built in 1949 at the South Charleston Plant. In the 1950s larger units were built at the Texas City, Seadrift, Torrance, Institute, Montreal, Grangemouth (Scotland), and Whiting Plants. By 1960, the Company had polyethylene capacity of 600 million pounds per year in the U. S.

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The manufacture of polyethylene was very profitable.

In the mid-1950s a new type of polyethylene appeared. It was a high-density material made at low-pressure by a catalytic process. The pioneering work had been done in the 1940s by Karl Ziegler at the Max Planck Institut in Germany. The low-pressure process involved a chain-growth mechanism that used metal alkyl catalysts. The costs were comparable to high-pressure polyethylene, but the product was different and had different applications. Standard of Indiana and Phillips Petroleum were also doing work in the area, and they had patented catalysts and processes. One of the problems with the catalysts was that they were contaminants in the final product and had either to be removed or the catalyst productivity had to be high enough to render the presence of the catalyst residue insignificant. Union Carbide licensed both the Ziegler Slurry Process and the Phillips Solution Process in the mid 1950s and built production units based on those processes at South Charleston and Institute, respectively. However, at the same time the Company embarked on its own process and catalyst studies that would culminate in the 1960s in the breakthrough development of the UNIPOL fluidized-bed gas phase process.

VISKING

In 1957, the Company acquired the Visking Corporation, whose principal products were cellulose food casings and polyethylene film for food wrap. The primary interest was the polyethylene film end of the business. However, Visking had pioneered "skinless" casings for sausages and frankfurters in 1926. "Skinless" sausages derived from a failed attempt to substitute cellulose tubes for animal intestines in making sausages, because animal intestines had been in short supply and were being imported from Mexico and China. During cooking of the cellulose-encased sausages, the casings separated from the meat and left a loose cellulose pouch with a sausage in it. However, it was soon found that the sausage meat had formed its own "skin" under the cellulose, and the sausage could be removed from the pouch and sold as such. Thus the "skinless" sausage was created. This food casing business proved to be an unexpected jewel.

In 1961, the Federal Trade Commission ordered Union Carbide to divest itself of the polyethylene film assets acquired from Visking as being in restraint of trade. Those assets were sold to the Ethyl Corporation in 1963. However, the Company was allowed to keep a polyethylene film plant in Cartersville, Georgia, that it

had built subsequent to the acquisition of Visking. The thriving sausage casing business was also kept.

Oxo Alcohols

In the early 1950s, a new process for making alcohols from olefins was introduced. The proper name for the process is hydroformylation, but it is called "oxo" for short. The basic technology was developed by Ruhrchemie in Germany just before the Second World War, and it became available after the war through the Combined Intelligence Objectives Subcommittee (a military and civilian group that gleaned German technology.) The process involved reacting an olefin with carbon monoxide and hydrogen (synthesis gas) at 6000 psi in the presence of a cobalt catalyst. The product was an aldehyde with one more carbon than the starting olefin. The aldehyde could be readily hydrogenated to the corresponding alcohol or reacted via an aldol condensation. Propylene, the most commonly used feedstock, yielded butyraldehyde and isobutyraldehyde in a ratio of six to four. The butyraldehyde could then be hydrogenated to butanol or aldoled to ethylpropylacrolein, which yielded ethylhexanol on hydrogenation. The economics were considerably more favorable than the traditional route. Higher alcohols could also be readily produced in tank reactors with other feedstocks. Oxo units with tank reactors were built at South Charleston, in 1955, and at Texas City. Units with tubular reactors were built, starting in 1957, at Seadrift, Texas and Ponce, Puerto Rico.

Silicones

Silicones, or more precisely siloxanes, are not petrochemicals—they're a different breed of cat. Silicones are semi-organic polymers in which various organic groups are pendant on silicon atoms which in turn are linked with oxygen. Care must be exercised to distinguish between silicon, an element, and silicone, a polymer. Silicon, which is chemically analogous to carbon and bonds with it well, is abundantly available in nature as silica (sand). Elemental silicon is produced by reducing silica sand with coke in an electric arc furnace in the same manner that calcium carbide is made.

The character of a silicone depends on the kinds of organic molecules that

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are attached to it. When the organic molecules are small or tightly combined (such as in methyl or phenyl groups), the polymers exhibit unusually good thermal stability and low-temperature flexibility as well as dielectric properties and an incompatibility with organic compounds. Such silicones and their manufacture were the inventions of the Corning Glass Company, later Dow-Corning, and the General Electric Company. Applications were found as resins, elastomers, adhesives, and lubricants.

Interest in silicones at Union Carbide originated with Dr. George O. Curme, Jr. in the late 1930s. He was intrigued with the work that was being done in silicones by Corning Glass and by General Electric, and he felt that there was promise in the field. Furthermore, the Electro Metallurgical Company was making silicon and ferrosilicon. As a result, the Corporation's Chemical Research Committee granted a research charter, first to the Electro Metallurgical Company in Niagara Falls and subsequently to the Linde Air Products Company in Tonawanda, to explore silicones chemistry. Research began in earnest in 1942 at Linde.

Initially, the interest was in making silane monomers and silicone polymers similar to those already being made but with different organic groups and thus different properties. (Silanes are the basic building blocks of the silicone polymer.) The early intent was to produce intermediates for sale to the silicones industry in the same manner that the Company had produced organic intermediates for sale to industry. However, pressures in the 1950s for financial returns led the Company into a program of aping some of the products made by Dow-Corning and General Electric. Despite a nine-year handicap in getting started, the Company was able to penetrate the existing market sufficiently to justify a commitment to the business and to provide time to successfully find its own place in the business. That place was hydrosilation chemistry, the coupling of silanes with organic chemicals where products exhibit in varying degrees the characteristics of both silane and organic chemicals. It's a high value-added specialties business where the Company became the market leader. Success was attributable in large measure to remarkable efforts in research, development, and marketing.

Several developments contributed to the early growth of Carbide's silicones business. The first was the development of water repellents (C-25 and R-23) for masonry and cement. Another was the development of vinylchlorosilane-based materials as coupling agents for fiberglass-reinforced plastics. The silane bonded to both the glass and the resin and prevented water absorption and the subsequent

loss of strength in the composite material. Further, compositions of the silicone coupling agent could be varied to suit the particular resin being used. It was, and is, a major factor in the successful application of fiberglass plastics.

Early operations were at Linde's pilot plant at Tonawanda. However, in 1954 - 1956, a large, free-standing silicones plant was built on the Ohio River near Sistersville, West Virginia. Actually, the plant is at Long Reach—a name from earlier river navigation days when this was a long straight stretch of the river—and at first was called the Long Reach Plant, but that name didn't stick, and the plant became known as the Sistersville Plant. At the same time, the whole effort was transferred from Linde to Chemicals and Plastics as the Silicones Division.

In 1961, the Silicones Division finally broke into the black and by 1965 had sales of $24 million compared to $2 million in 1955. (Worldwide sales would eventually reach over $400 million per year in the 1990s.) Part of the reason for the success of the business was the development in 1959 of silicone surfactants for urethane foams. The silicone surfactant (L-520) while only ½ percent of the foam formulation, made possible the "one-shot" urethane foam process. In the process, the silicone surfactant promotes the mixing of reactants, controls the cell size, and stabilizes the foam. This breakthrough helped create large foam markets with many applications and also promoted the sale of Union Carbide's polyols and isocyanates, the basic foam raw materials. In 1959, the Silicones Division also began supplying high-purity trichlorosilane to the infant semi-conductor industry for the production of hyper-pure crystalline silicon for computer chips. Tank-truck shipments of semi-conductor trichlorsilane began leaving the plant in 1960.

The Silicones Division entered the overseas markets in 1956 with export sales. By 1963, silicones exports were a third of divisional sales. Small manufacturing and blending facilities were built in the late 1960s in Belgium, Brazil, Mexico, and Australia. A technical service laboratory was also set up in Versoix, Switzerland. While the cost of the high-margin silicones were not a large factor in the user's costs, poor performance could have major consequences, and retention of sales and sales growth hinged heavily on tech service to the customer.

Three basic market areas eventually evolved in the Silicones Division. There were: organofunctional silanes—which bond to a wide range of inorganic and organic products; urethane additives—silicone copolymers which facilitate foam processes; and specialty fluids—a large group of surfactants, antifoams, fluids, and emulsions. Each accounted for roughly a third of the total business. The resins

and elastomers businesses were pretty much exited by the late 1960s.

Polystyrene

Bakelite started to produce polystyrene at Bound Brook in 1937. However, the growth of polystyrene did not take off until after the second World War. At that time, Union Carbide, along with the Dow Chemical Company, Monsanto, and the Koppers Company all had large styrene plants that had been built during the war for the wartime rubber program, and they were all seeking outlets for that capacity in the form of polystyrene. Carbide built its second plant at Marietta, Ohio, in 1955, based on the bulk polymerization process. The product was a very viscous material and difficult to remove from the reactor and to degas. Special gear pumps were used to get it out of the reactor, and Walter Marshall, of Bound Brook, invented a mill to process the product and remove the volatile materials prior to extrusion and pelleting. The mill was quite successful and gained acceptance in polymer processing as the "Marshall Mill."

The production and sale of polystyrene continued until 1977 when the business was sold to the Gulf Oil Company. They retained the Marietta Plant, and the Bound Brook Polystyrene Unit was razed.

Agricultural Products

The 1950s also saw the rise of the Agricultural Chemicals business at Union Carbide. Ethylene had been known and used for a long time as a ripening agent for fruits and vegetables, and ethylene oxide had been used a fumigant since the 1920s, but serious interest began in 1931 when Dr. George H. Law, the Director of Research for Chemicals, proposed research in the area. He was encouraged and supported by Dr. Curme, and work began actively in 1936 at South Charleston.



Figure XXIV
Sistersville Plant in 1981

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The early interest was in pesticides. Research was carried on cooperatively with Boyce-Thompson Institute in Yonkers, New York, where Dr. Law had established a fellowship to screen chemicals for their biological activity. The driving force behind the Agricultural Chemicals program for Union Carbide became Dr. Richard H. Wellman, a plant pathologist, who was hired in 1939 to work with Boyce-Thompson. Boyce-Thompson is a research institute, now located at Cornell University in Ithaca, New York, which is dedicated to basic research in agriculture.

The Agricultural Chemicals business was an entirely different kind of business from the usual petrochemicals and plastics at Union Carbide. It needed special testing, government approvals, and marketing plus the education and servicing of end use consumers, as well as intensive research in discovery, product development, and toxicology. The products were neither commodity chemicals nor consumer products and a strange breed to most "Carbiders."

The first product made and sold, in the 1940s, was CRAG 6-12 Insect Repellent, chemically 2-ethyl-1,3-hexanediol. It was used widely by American troops in the field during World War II. The breakthrough in Agricultural Chemicals came about in the 1950s with the discovery, by Dr. Joseph Lambrech, of a broad spectrum insecticide with low mammalian toxicity trademarked CRAG SEVIN, and chemically named 1-naphthyl-N-methyl carbamate. It was a very effective insecticide and could be used safely by home gardeners and by peasant farmers in undeveloped countries without special training or precautions. It was first produced on a temporary basis in modified facilities at South Charleston and Institute, and then in 1960 in a 50 million pounds per year dedicated facility at Institute. SEVIN gained special notice in 1960 when several million pounds were airlifted to Egypt on an emergency basis to save the cotton crop there from an infestation of army worms. SEVIN became the most widely used pesticide in the world.

Molecular Sieves

In the late 1940s, Dr. Robert M. Milton of Linde began basic studies on zeolites at Tonawanda, New York, with an eye to using them as adsorbants for separating oxygen and nitrogen. Zeolites are natural products that are chemically similar to clay but which have some special structural properties. The structure consists of a three-dimensional lattice framework that permits molecules of differ-

ent sizes to be selectively adsorbed in the micropore interstices. Milton's idea was to make a synthetic zeolite inasmuch as natural zeolites are very rare. By 1950, Milton had succeeded in developing a process to make synthetic zeolites from silica and alumina. He also identified the three basic forms of zeolite, dubbed A, B, and C, and their structures. The term that was used to describe these synthetic zeolites was "molecular sieves."

Molecular sieves were first manufactured and sold by Linde in 1954—only five years after their discovery. Their uses proved to be widespread and significant. These uses included adsorption for physical separations and catalysis in catalytic cracking, isomerization, and hydroforming of petroleum. They were also used as an environmentally-friendly substitute for phosphates in detergents. Linde was awarded a KIRKPATRICK CHEMICAL ENGINEERING ACHIEVEMENT AWARD in 1961 for the development of synthetic zeolites. Milton was awarded CHEMICAL PIONEER AWARD of the American Institute of Chemists in 1980 for his work.

Further development on molecular sieves was picked up by Edith Flanigen, first at Tonawanda and then in the Company's Tarrytown laboratories. Under her direction, a whole new stable of synthetic zeolites was developed. These new zeolites included silicon, phosphorus, and various metals in their makeup. This new generation of molecular sieves is recognized as a landmark discovery in the field of inorganic chemistry. Flanigen was awarded the prestigious PERKIN MEDAL of the Society of Chemical Industry in 1992 for her contributions. She was the first woman to receive the PERKIN MEDAL.

The molecular sieve business developed and prospered and is a billion dollar industry today. Molecular sieves were first made and marketed by Linde and then as a separate group associated with Chemicals and Plastics. The first molecular sieve plant was in Mobile, Alabama. In 1988, the molecular sieves group was folded into UOP (formerly Universal Oil Products), a joint venture with Allied-Signal, and was Union Carbide's most important contribution to that venture.

DYNEL

Union Carbide developed a textile fiber in the late 1940s that was trade named DYNEL. It was made from a copolymer of vinyl chloride (60 percent) and acrylonitrile (40 percent). The fiber had a wool or fur-like texture and appearance

and found excellent application in wigs, simulated fur coats, carpets, and industrial filters and cloths. (The New York office at 270 Park Avenue was covered with 70,000 square yards of Dynel carpeting when it was built in 1959.) However, DYNEL was very heat sensitive and limited on that account. A DYNEL resin unit was built in 1950 in the VINYLITE area at the South Charleston Plant, and a spinning unit was built outside the plant, but also at South Charleston, to make DYNEL tow and staple fiber. The initial capacity of the system was six million pounds per year, which was increased in 1964 to ten million pounds per year.

DYNEL was a good product, but as it turned out, a niche product. In the early 1950s, the Company contemplated getting into the fibers business in a big way, and indeed, bought a large site near Spray, North Carolina, for that purpose. However, such a venture required a huge infusion of capital, and the idea was ultimately abandoned. DYNEL operations were continued at South Charleston until 1975, at which time they were shut down, because substantial new investment was required to keep operating.

Coal Hydrogenation

In the late 1930s, Dr. George O. Curme was concerned about the availability of feedstocks in the long term for the Company's operations. Quantities of natural gas in the Eastern United States were declining and an end to the supply was being projected. Indeed, the federal government was forecasting that the Country would run out of natural gas in ten to twenty years. At that time, no one foresaw the huge discoveries of gas and oil in the Middle East, in Africa, in Alaska, and in the North Sea. While Union Carbide's immediate future was secure with an ample supply of refinery off gases, the oil companies were showing an interest in using those materials for their own operations. Union Carbide already had experimented with running its own oil refinery (the "Gyro" unit at South Charleston) to make feedstocks for olefins plants. However, Dr. Curme felt that, ultimately, abundantly available coal would be the resource that would provide the most secure supply of feedstocks. Coal, of course, can be used to make synthesis gas, which in turn can be used to make aliphatic chemicals. However, this is not what Dr. Curme had in mind inasmuch as coal, in effect, has to be burned to make synthesis gas. What he hoped to do was make an array of chemicals directly, or nearly so, by coal hydrogenation.

To that end a pilot unit was built in 1937 at the South Charleston Plant to explore the hydrogenation of coal at temperatures up to 500°C and at pressures up to 6000 psi. Similar studies were going on in Germany and England and also by the U. S. Bureau of Mines in this country. However, those studies were directed more toward producing liquid and gaseous fuels rather than chemicals.

Coal hydrogenation studies continued in the pilot unit until 1949. At that time it was decided to build a 300 tons per day (of coal) demonstration plant at Institute, West Virginia. Dr. George T. Felbeck, who had superbly managed Union Carbide's wartime ventures, was placed in charge of the whole effort—concept, design, construction, and operation. Felbeck visualized a multifaceted, integrated approach that included the automated mining of coal, the generation of power, the gasification of coal to make synthesis gas and hydrogen, a Fischer-Tropsch process to make feedstocks for olefins, the hydrogenation of coal to produce aromatic chemicals, and the production of coke for carbon electrodes and activated carbon. Work on the demonstration plant, and its supporting facilities, started in 1948. The plant was finished in 1951 and operated until 1956. Many of the people involved came from the Oak Ridge operation and from the Methanol Plant in Niagara Falls, which had been shut down about that time.

The problems were horrendous—handling and processing hot erosive coal slurries and hydrogen at high pressures. Operation was very erratic. The plant achieved a modicum of success from a technical standpoint—the Company received a KIRKPATRICK AWARD FOR CHEMICAL ENGINEERING ACHIEVEMENT in 1953 for the project. However, it was kind of an "A" for effort. In the end Curme's hopes were neither feasible nor economic, and the venture could not stand on its own. A major factor affecting the economics was the increasing availability of natural gas and petroleum supplies. However, the concept did not die immediately. Proposals to make phenols and cresols by coal hydrogenation were continued until 1963 when the whole thing was finally put to rest. The concept of making chemicals directly from coal by way of coal hydrogenation may one day be a valid one, but it will not be so until petroleum is in much shorter supply. A record of Union Carbide's technology has been preserved for that day.

Nuclear Programs

The Atomic Energy Commission (AEC) was formed in 1946 to put nuclear energy under civilian control, and the AEC continued Union Carbide's contract to run the K-25 Gaseous Diffusion Plant at Oak Ridge. Carbide also assumed responsibility at that time for the Oak Ridge National Laboratory and then a year later for the Y-12 Electromagnetic Separation Plant. Thus, in 1947, Union Carbide was responsible for the whole complex at Oak Ridge. However, the Y-12 Plant was shutdown in 1947 for separating uranium isotopes and was converted to the manufacture of nuclear weapons parts. In the early 1950s, Carbide also assumed responsibility for a new gaseous diffusion plant that was built at Paducah, Kentucky. All of the nuclear facilities were managed on a cost basis and a fee was charged to cover only the cost of administration. The Company contributed to both management and technology. In 1969, Union Carbide received a KIRKPATRICK AWARD FOR CHEMICAL ENGINEERING ACHIEVEMENT for improvements in the gaseous diffusion process for enriching uranium.

In 1955, the Corporation formed a Nuclear Division to integrate and manage its whole nuclear effort. A further objective was to carry on extensive research and development work in the field of commercial and industrial applications of atomic energy. At its peak in 1975, the Nuclear Division had 15,000 employees—mostly associated with the government programs. The commercial part of the Nuclear Division included the mining and milling of uranium ores in Colorado and Utah. It also included a venture in 1960 into a five megawatt nuclear "swimming pool" reactor at the Sterling Forest Research Center near Tuxedo, New York. The intention was to use the reactor for research and radioisotope production, particularly for medical purposes. However, the field was crowded, competitive, and not very attractive. As a result, the reactor was sold in 1980 to Hoffman-La Roche, a pharmaceutical manufacturer. They shut it down in 1982 and converted it to a greenfield site.

Computer Automation

In 1957, Union Carbide set out in concert with Ramo Wooldridge to effect computer control of a complex process. The process selected was the ethylene oxide process—actually the unit at Seadrift, Texas. Work already had been done

on data collection and off-line optimization. Full closed-loop, optimizing, computer control was achieved in 1959—a world's first. Other processes followed, especially Olefins Units. (Texaco brought a computer controlled process online a year-and-a-half later and received credit for being the world's first, because Carbide kept its accomplishment under wraps for competitive reasons.)

Environment, Safety, And Health

Personnel safety has always been a matter of importance at Union Carbide. Company safety records go back to the mid-1920s, and these safety records over the years tend to be about four times as good on average as industry as a whole. This is in spite of the fact that many of the Company's operations and materials are potentially hazardous. Indeed, the very fact that there is possible exposure to hazard has driven the Company's safety programs from early on. However, in the early days, safety was mostly a local matter and the role of the Corporation was mainly encouragement through policy. Nonetheless, many national safety awards were received, and the Company's safety record remains exemplary to this day.

Concern for health has also been a long-term priority at Carbide. In 1937, a Chemical Hygiene Fellowship was established at the Mellon Institute to test all Carbide products and their intermediates to determine toxic effects and limits based on breathing, ingesting, and skin exposure. The results of the tests were made available to employees and customers as "Toxicity Information Sheets", forerunners of the federally mandated "Material Data Safety Sheets". Routine physical examinations have also long been a part of the industrial health program. Industrial hygienists have routinely monitored plants since 1960.

In the 1930s, however, it became apparent that formal attention was needed for process safety as much as for personnel safety. Efforts were put forth in the areas of fire prevention, fire protection, pressure relief, and fail-safe shutdowns. In the mid-1940s, a Fire Research Laboratory was established at the Institute Plant to study the behavior of chemicals exposed to fire. Although no one was seriously injured, an explosion of a railroad tank car in 1954 at the Institute Plant (caused by a reaction initiated by filling the car through a contaminated pipe) triggered an intensive effort to assure safety in design and operations. The first step was to document potentially reactive chemical hazards plus fire safety and health hazards. This resulted in the publication of a three-volume "Reactive and Hazardous

Chemicals Manual", which became another predecessor of the "Material Data Safety Sheets". The tank car explosion also triggered the institution of formal, exhaustive Safety Reviews and Safety Considerations Reports for all process designs.

The environmental program got off to a slower start. Consistent with the rest of society, typical environmental devices in the 1920s and 1930s were rudimentary ash collectors for boilers and flares to burn flammable exhaust gases. Many people burned soft coal in their home furnaces or fireplaces and the smoke from an industrial stack wasn't much noticed. With the post-war growth of industry, the problems were exacerbated—from the standpoints of both air and water pollution, and it was obvious that something needed to be done. Prior to 1945, many rivers were open sewers, receiving untreated municipal wastes as well as taking the outfall of industrial plants. The first steps were taken to correct the problem in the 1950s. These included waste abatement (that is, the avoidance of waste) and segregating and collecting waste streams and treating them. The older plants were more difficult to deal with. Efforts were put forth on municipal wastes as well as industrial.

The first objective was generally to reduce the 5-day BOD (Biological Oxygen Demand) of the water, a measure of oxygen content and indirectly of the level of pollution. Linde devised a system, called UNOX, for treating wastes with oxygen, which was particularly successful in Japan. The South Charleston Plant and the City of South Charleston joined together in 1956 to design and construct a plant to handle their combined wastes. (It's still in operation today.) The Torrance Plant was built to meet newly established air and water pollution standards of Los Angeles County. The Texas City Plant constructed a series of lagoons in the late 1950s for treating their wastes. The Seadrift Plant also had a series of large waste treatment ponds. Standards were state or regional and varied from place to place. The Ohio River Basin came under the jurisdiction of the Ohio River Valley Sanitary Commission (ORSANCO), an eight state compact authorized by federal legislation to help clean up the water. The problems were enormous. Ready solutions were not readily available, and when solutions were available, they were generally expensive. There was much left to do.

Chapter Five
GROWING PAINS (1960-1970)

"Summertime and the livin' is easy" might have been the theme song for Union Carbide in the early 1950s. However, by the 1960s, things had changed. Heavy competition had arrived and many of Carbide's dominant positions were being challenged. Scientific Design, Inc., a process engineering contractor, was marketing an ethylene oxide (and glycol) process worldwide that was very similar to the Union Carbide process. The Shell Oil Company had developed and was licensing an oxygen-based (as opposed to air-based) oxide process that was competitive—in fact, the oxygen-based oxide processes eventually became the process of choice and Union Carbide developed one as well. Many others were making polyethylene, vinyl chloride, vinyl resins, phenolic resins, etc. The technologies for these processes had become available through expiring patents and diffusion occasioned by the movement of people. Engineering contractors, privy to much technology, facilitated newcomers. However, entry into the market and plant expansions were often not rational. As a result, there was often surplus capacity and markets were frequently chaotic with much price competition. Some in the Company felt that the bloom was off the rose insofar as the basic petrochemicals business was concerned.

The 1960s were also an era of cultural and political upheaval. An unpopular and growing war in Vietnam had created a general air of discontent and triggered violent protests. There was overt opposition to the "establishment"—both political and business. The Institute and South Charleston Plants were organized in 1967 and 1968 by the Oil Chemical, and Atomic Workers' union (OCAW). There was also increasing public challenge to environmental problems. The political turmoil did not reach directly into Union Carbide (except for the environmental problems), but the Company was experiencing growing pains.

The question that faced the Company was whether to stay with established positions and fight or to seek new opportunities. Diversification was all the rage at the time, and the conglomerate ITT (formerly International Telephone and Telegraph) under Harold Geneen was the personification of diversification and was the favorite of the stock market. The answer that the Company settled on, influenced

by the pressures of the market and the spirit of the times, was to diversify and seek new opportunities. Linde had a knack for incubating new products outside its main product line—such as olefins, polyethylene, silicones, molecular sieves—and this lesson surely was not lost on the planners. The extent to which diversification was right or wrong for Union Carbide is moot, but it affected just about everything that happened at Carbide after that.

Union Carbide's business had always been cyclical, being tied to the ups and downs of the economy—especially the steel and automobile businesses—but in the absence of serious competition, margins had usually been good. Now, margins were smaller and frequently unappealing. Fields that looked greener were specialty products, where there was more value added and more room for profit. It is interesting to note that while Union Carbide was contemplating new business areas, others coveted Union Carbide's green fields. Indeed, the PYROFAX gas business was sold to Texas Eastern Transmission Company in 1962. PYROFAX, which had carried the Chemicals Company in the early years, was no longer attractive, because there was no longer low-cost byproduct liquified petroleum gas (LPG) from chemicals feedstocks and the Company was having to buy LPG on the open market for resale.

There was no dearth of opportunities. Perhaps just the opposite was true. Union Carbide had grown successfully in the past by exploiting its own technologies, and Research and Development was still liberally generating new opportunities. Coupled with the search for outside opportunities, there simply were not the resources, people or money, to exploit all the things people would like to do and still maintain a healthy position in established businesses. Inasmuch as the glamour areas were the new opportunities, some of the established areas withered, for example vinyl resins, phthalate plasticizers, polystyrene, and phenolic resins. Ironically, the two vinyl resin processes that survived were the earliest ones, the solvent resins process (at Texas City) and the polyvinyl acetate process (at South Charleston).

The Company did diversify and with some success, but this was mostly as home-grown adjuncts to established lines—such as polyurethane foams, latexes, TEMIK (a systemic insecticide), and molecular sieves. Other real strengths in the 1960s included a new low-pressure oxo process (LPO), a butane oxidation process for making acetic acid, and a new, impregnated ethylene oxide catalyst that increased existing ethylene oxide capacity by 300 million pounds per year.

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Low Pressure Oxo

In the late 1960s, the Company developed a low-pressure oxo (LP Oxo) process that uses a rhodium catalyst and that has proved to be a real winner—over half of the world's butanol is made by this process today. The process enjoys a huge advantage over the high-pressure process in that it operates at about 200 psi instead of 6,000 psi and produces normal butyraldehyde (the desired product) in a ratio of ten to one over isobutyraldehyde (the byproduct) instead of the six to four in the high-pressure process. The operation is also very trouble-free. Research and development for the process was done primarily by Union Carbide. However, Davy Power Gas Company, an engineering firm in the United Kingdom, and the Johnson-Matthey Company, a precious metals company, also participated. A joint venture for licensing was set up with Davy being the primary marketer and Johnson-Matthey supplying the rhodium catalyst and reprocessing the spent catalyst. Union Carbide converted most of its high-pressure units to the LP Oxo process in the 1970s. It won another prestigious KIRKPATRICK CHEMICAL AND METALLURGICAL ENGINEERING AWARD for the LPO process in 1977. In 1998, Dr. David W. Bryant of the South Charleston Technical Center received the Perkin Medal for his contributions to the LP Oxo process.

Losers

Unfortunately, too many of the other new directions that were tried were ill-advised. These included a foray into making men's hats from polyurethane foam (SURFEL) just as men's hats were going out of style; getting into and out of the mattress business (the Englander Mattress Company) to promote the sale of polyurethane foam and losing a big bundle in the process; a failed attempt at getting into manufactured housing where the Company was going to revolutionize home construction but where it dropped another large amount instead; getting into the diaper business in which the Company had a good product (DRYDEES) but had production problems and was out of its league in retail marketing against a 600-pound gorilla (Proctor and Gamble); and getting into and out of the pharmaceuticals business (Neisler Laboratories) where the Company hoped to exploit its skills with fine chemicals in a "synergistic" fashion, but where a match never occurred. There were other things like fish farming, which was backed into from Linde's

Oceans Systems, solid rocket fuels, the mining of oölitic aragonite (limestone) from the sea, a wet coal mine, and others, most of which are better forgotten now.

Organization

There were more than 115,000 employees in all of Union Carbide by the end of the 1960s (which included about 14,000 people in the Nuclear Division at Oak Ridge, Tennessee, and Paducah, Kentucky.) To cope with the management of such a large venture, the Corporation was divided up into four groups in 1964. These were: Group 1—Chemicals and Plastics including the Chemicals Division, the Olefins Division, the Plastics Division, and the Silicones Division; Group 2—Carbon Products, Gases, and Metals including the Carbon Products Division, the Linde Division, the Mining and Metals Division, and the Stellite Division; Group 3—Consumer and Related Products including the Consumer Products Division, the Fibers and Fabrics Division, and the Food Products Division; and Group 4—International, including Union Carbide Canada, Limited, and the Union Carbide International Company. Other free standing groups included the Nuclear Division and the Realty Division. (In 1968, the numbering changed to roman numerals, and the groups became Group I, Group II, Group III, and Group IV.) In May of 1966, the International Company was dissolved and in its place three world area companies were formed. These new companies were Union Carbide Europe, Union Carbide Eastern, and Union Carbide Pan America—which included Union Carbide Canada. (In 1970, Union Carbide Canada was detached from Union Carbide Pan America and tied in to the senior officer serving on the Union Carbide Europe board.)

To deal with the its own problems of size and complexity, Group I established a matrix organization in 1964. A matrix organization keeps intact the large functional elements of a company (such as research & development, engineering, manufacturing, distribution, sales, etc.), but sets up small dedicated groups organized by business area to direct (but not administer) the efforts of the functional groups across the board to the needs of a business area. At Union Carbide these groups were called "business teams" and they had a responsibility for individual business areas. The matrix system was in use at the time in other large organizations, such as the aircraft industry. In Chemicals and Plastics, however, there were two matrices rather than one. The first matrix involved operations groups struc-

tured around a group of products. These groups were responsible for the development, manufacture, distribution, and sale of products. The second matrix involved marketing groups, and was concerned with specific markets and servicing those markets. A typical Operations Team consisted of an Operations Manager, reporting to a Vice President/General Manger, plus a Production Manager, a Product Manager, a Technology (R&D) Manager, an Engineering Manager, and a Distribution Manager. The five sub-managers were administratively part of the functions that they represented. There was no other staff. The Market Area Teams were organized along similar lines but were more loosely structured. The matrix organization was in use to 1980.

Sales and Facilities

World-wide sales for the Corporation increased from about $1.5 billion in 1960 to about $3 billion in 1970. Earnings, however, stayed flat owing, in part, to severe price erosion and averaged $180 million per year over the decade. Construction expenditures for the period amounted to about $3 billion, about one-quarter of it overseas.

Chemicals and Plastics operations reached capacity levels in 1966, and much new capacity was under construction. Major chemicals and plastics complexes were built in 1964 at Bombay, India, and in 1965 at Antwerp, Belgium. Each of these sites already had a polyethylene unit. Other major chemicals and/or plastics facilities were built in 1961 at Cubatao, Brazil, in 1962 in Japan, in 1963 at Stenungsund, Sweden, and in 1963 in Australia. Substantial expansions were made at many of these sites over the remainder of the decade.

In the United States, there were numerous expansions at existing plants, a notable one being a 1.2 billion pounds per year olefins unit at Texas City (Olefins Unit No. 3) which came on stream in 1969. At the time, this was the largest olefins unit ever built. It was designed to operate mainly on refinery off gases. The in-house designed and managed unit came in on time and within budget and started up flawlessly. It was a fully automated plant run by computer and was able to control production rate, product quality, and maximize gross margin.

Progress also was being made on the waste abatement front. The Company pioneered the development and use of an automated gas chromatograph to monitor waste waters. In this fashion, specific organics in the wastewater could be iden-

tified and traced back to the source and corrective action taken. The Company also developed clay-lined solid waste landfills with leachate collectors. These were prototypes for what became an industry standard.

Two major new plant sites were opened up for Chemical and Plastics in the 1960s. The first plant was at Taft, Louisiana. It was designed and built in the period 1964-1965 and started up in 1966-1968. The second was at Ponce, Puerto Rico, and was designed and built in 1969-1971 and started up in 1972.

The Taft Plant was built at a site on the Mississippi River above New Orleans. The site was chosen to provide access to river transport (barges) and deepwater shipping (tankers). It was also to be designated a free-trade zone where foreign naphtha could be shipped in and products exported on a tax-free basis. Naphtha was the feedstock of choice for the plant, because concentrates and refinery off gases were less available and becoming more expensive. The facilities involved were an Olefins Unit, Ethylene Oxide and Glycol Units, an Ethyleneamines Unit, an Acrylic Acid and Derivatives Unit, a Peracetic Acid and Derivatives Unit, a Glyoxal Unit, and a Caprolactone and Caprolactam Unit, plus all of the necessary infrastructure. The Olefins Unit was purchased from the Lummus Company, because Lummus had experience cracking naphtha and Union Carbide did not. Numerous contractors were involved with the plant, and there were difficulties in construction and startup. Eventually, however, the plant became a top-notch operation.

The plant at Ponce, Puerto Rico, came into being to take advantage of access to low-cost foreign feedstocks (naphtha), assured low-cost power (one-half cent per kwh), and a seventeen-year tax holiday on earnings. It was to be put on the site of the existing smaller complex. The Carbon Products Division also built a new electrodes plant at Yabucoa, on the east end of Puerto Rico, on the basis of the same incentives. The new plant at Ponce was one of the largest ever built and would include a billion pounds per year Union Carbide designed naphtha-based Olefins Unit, an Ethylene Oxide and Glycol Unit, a Polyethylene Unit, a Cumene Unit, a Butadiene Unit, a Glycol Ethers Unit, a Phenol-Acetone Unit, and a Bisphenol-A Unit. Also included in the project were utilities, waste treatment facilities, field storage facilities, and a deep water (tanker) terminal.

The whole operation came off extremely well. To quote from Union Carbide's Annual Report for 1972: "Although the Ponce petrochemicals facility was described by its builders as the most complex job they had ever undertaken, the

project was finished ahead of schedule and on budget. It was the petrochemicals industry's largest single project, capable of producing four billion pounds of products per year. The startup of this plant was considered one of the most trouble-free in the industry in recent years, and the plant has operated at rates in excess of design capacity. It is expected to generate earnings in 1973 of 20 to 25 cents a share." Unfortunately, as the energy crisis struck in 1973, the economics changed. Foreign raw materials became expensive and power costs increased by a factor of ten. That plus the costs of operating offshore eventually rendered the plant uneconomic and it was shutdown for the most part in January of 1985.

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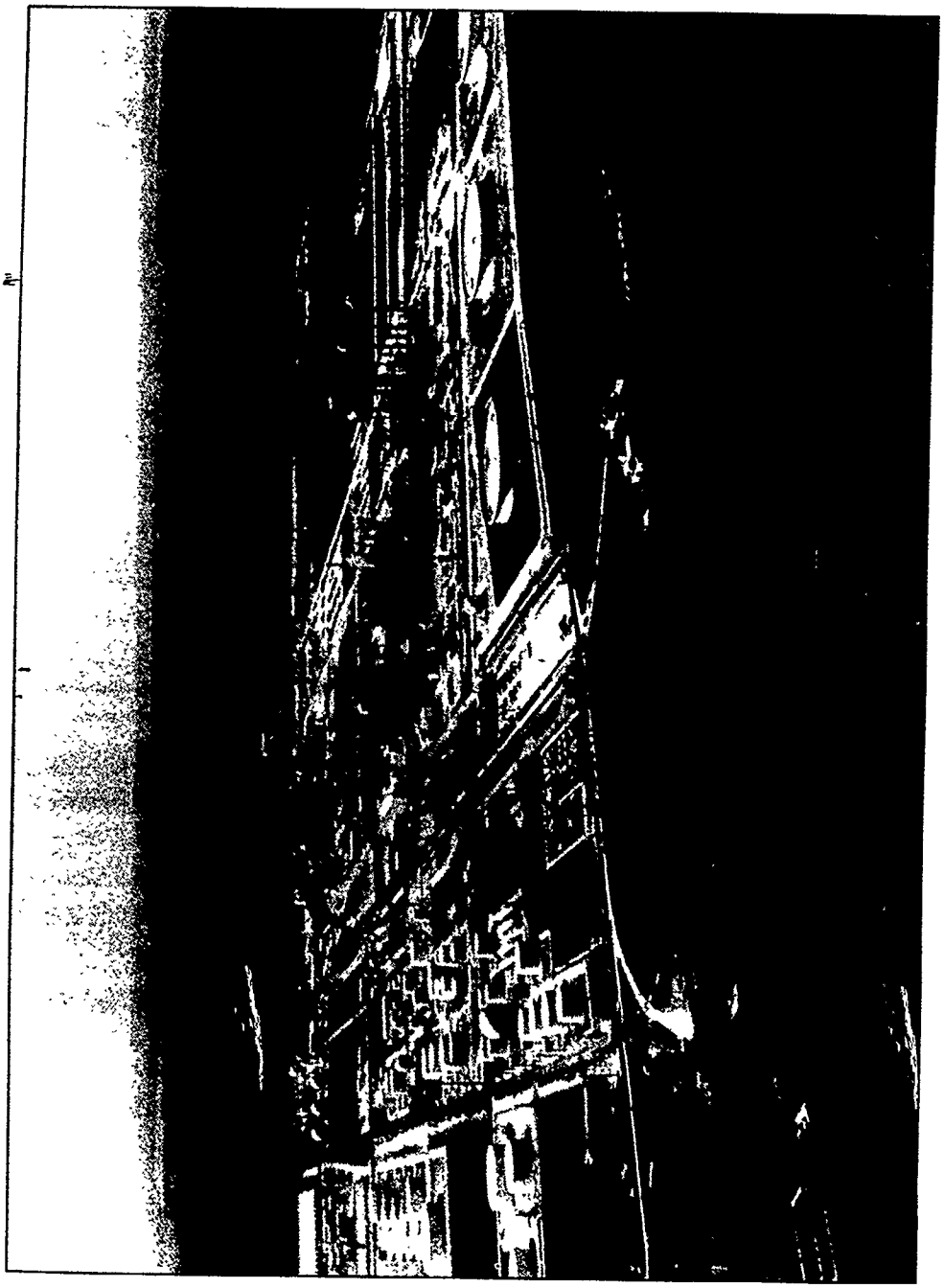


Figure XXV
Taft Plant in 1968



Figure XXVI
Ponce Plant in 1972

Chapter Six
ENERGY CRISES AND INFLATION (1970-1980)

The story of the 1970s was one of turmoil driven by energy crises and inflation. These were factors that no one controlled and that affected the whole world. Energy equated with oil, but in Union Carbide's case energy meant more than just heat and power—it also meant raw materials. It was especially significant for the Company, because—apart from the nuclear operations—it used one half of one percent of all the energy in the United States. However, on the bright side, the 1970s were also the time that the Company's low-pressure polyethylene process (UNIPOL) came to fruition.

The first energy crisis occurred in late 1973 and was both a crisis and a panic—it happened and people scrambled to cope not knowing what they were in for. There had been a recession in 1970, but the economy had come out of it and was booming in 1973. Production was full out and raw materials were in short supply. The Organization of Oil Producing and Exporting Countries (OPEC) took advantage of this situation and began to raise oil prices. Inasmuch as OPEC controlled much of the world's crude oil supply, they were able to do so effectively. The price of crude oil rose from about $2 a barrel in 1972 (an extremely low price by any measure even then) to $7 a barrel in late 1973 and then to $11 a barrel in early 1974. Spot prices went as high as $17 a barrel. (For comparison, crude oil prices today—1997—are about $18 - $20 a barrel.) The shortage of oil in the United States was exacerbated by a partial embargo by Saudi Arabia on shipments to the States in retaliation for American support of Israel in the Yom Kippur War in 1973.

Domestic feedstock prices were less volatile. The Federal Government had imposed wage and price controls earlier, and "old" oil produced in the United States was subject to price controls. "New" oil, that is, oil discovered after a certain date, was not subject to the same controls. As a result, there were significant dislocations. Anyone with access to "old" oil had a decided advantage. However, anyone dependent on foreign or "new" oil was hurting. This was especially true of the Ponce Plant which had been operating on Venezuelan naphtha—which went almost overnight from being a bargain to being a premium priced product.

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The movement of oil prices dragged along other energy costs such as gas and coal. Federal wage and price controls were somewhat of a boondoggle and complicated the picture—in any event they were removed in 1974. Prices of manufactured goods for domestic consumption were increased where possible to compensate for the increased energy costs. As a result, inflation set in and the Consumer Price Index increased by over 110 percent in the 1970s. There was an illusion of prosperity at times as sales rose dramatically. However, the increase was sales income and not sales volume, and selling prices did not rise fast enough to cover increased costs. Eventually the piper would have to be paid, and the payment came in the form of a recession in 1975.

There was a second oil crisis in 1978. Iran was taken over by religious militants who were not much interested in things temporal. In the process of their revolution, they destroyed much of Iran's oil producing capacity. They also went to war with neighboring Iraq, which hampered that country's ability to ship oil. The combination of those events served to produce oil shortages and cause price increases again. The price of oil shot up to $23 a barrel in 1979 and then to $30 a barrel in 1980. Again there was inflation followed by recession.

There were serious consequences to the oil crises beyond the impact of cost. One was that unstable circumstances made it difficult to measure the health of current businesses. Another was that major uncertainties made it difficult to plan. As a result, the tendency was to get your head down and wait things out. Nonetheless, a Feedstock and Energy Council was established at the Corporate level to assure raw material supplies, and strong efforts were made to identify business opportunities and better allocate resources. But it was a hard time to invest; speculators profited but almost everybody else lost. One thing was apparent, however, and that was the need for energy conservation. With cheap energy, there had not been much incentive to save. Now, with expensive energy, it was obvious what had to be done, and much time and effort was put into making existing plants more energy efficient.

Several plants were shutdown or sold during this period. The plant in Whiting, Indiana, was shutdown in 1975. It had been in operation for forty years and was producing high-pressure polyethylene and isopropanol at the end. The plant in Antwerp, Belgium, was sold to British Petroleum in 1978 along with much of Union Carbide's chemicals and plastics business in Europe. This divestiture reflected a desire to concentrate on operations where the Company had a leading or

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strong position. The problem in Europe was the lack of a strong raw material base. (However, the Company did not pull out of Europe entirely—other operations and export sales continued.)

In 1973, the Company shutdown a Wulff Process Unit that had been recently constructed for Union Carbide do Brasil near San Paulo. The purpose of the unit had been to make ethylene and acetylene for a high-pressure polyethylene unit and a vinyl chloride unit. The Wulff process makes ethylene and acetylene as co-products of the high temperature cracking of naphtha in a regenerative furnace. The concept was a good one, but the project was a costly failure. The problem was poor design. The basic process was purchased from the Wulff Acetylene Company of Maywood, California, and translated into hardware by Union Carbide. Unfortunately, the process had not been sufficiently developed and was not able to run at more than 15-20 percent of capacity. The primary deficiencies were low yields of ethylene and acetylene and low on-stream time for the furnaces due to coking and fouling. Heroic efforts were made to revive the unit but to no avail. The Wulff Unit and the Vinyl Chloride Unit were taken out of service and scrapped. It was an expensive venture, and a $23 million write-off was taken. Ethylene was purchased instead for the Polyethylene Unit. (Oil-poor Brazil for a long time made its ethylene by dehydrating ethanol, which was made from sugar cane.)

UNIPOL — Low-pressure Polyethylene

The bright and rising star of the 1970s (and the 80s and 90s) was Union Carbide's low-pressure, gas-phase, fluid-bed polyethylene process called UNIPOL. The UNIPOL process came into its own in the 1970s as the high-pressure polyethylene process reached its peak. (The low-pressure process operates at several hundred psi compared to 30,000 psi to 50,000 psi for the high-pressure process.) Polyethylene had always been a substantial money maker for the Company, but the UNIPOL process represented an order of magnitude improvement over older processes in that capital costs were substantially lower and energy costs were also substantially lower. Further, the process accommodates the manufacture of a wide range of polyethylene and polypropylene products.

The UNIPOL process did not spring full-fledged from under a cabbage leaf. It came instead from sustained efforts to invent and develop new processes and catalysts that would yield superior economics. The Company had started studies

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on low-pressure catalysts in the mid-1950s after Phillips Petroleum and Karl Zeigler, among others, had demonstrated that the catalytic polymerization of polyethylene was feasible. Union Carbide secured licenses from Phillips and Ziegler at that time and built plants to make low-pressure polyethylene. The Phillips and Ziegler units made high-density polyethylene and were based on solution and slurry polymerization, respectively. Union Carbide's efforts, however, focused on gas-phase polymerization and organometallic catalysts. Catalyst work was done under Dr. Wayne Carrick, Dr. Fred Karol, and Joseph J. Smith at Bound Brook and under Dr. Thomas Wilson at South Charleston. Process development work was done at South Charleston. In a prescient moment, James M. Davison, a process development engineer, postulated in 1956 "a dry polymerization process wherein the olefin is blown through the catalyst on polymer keeping the particles in a fluid state. The olefin would be vaporized if a fluid or used directly if a gas. This 'fluidized bed' technique would lead to more efficient heat transfer and enable continuous addition of catalyst and removal of polymer." This fluidized bed process became a reality, and the characteristic bulbous-top fluidized-bed reactor became the hallmark of the UNIPOL process.

Catalyst studies and bench-scale and pilot-scale process studies culminated in a successful process which made not only high-density polyethylene but also—eventually—low-density polyethylene at considerable advantage over competing processes. Although the Company had made considerable improvements in its high-pressure process, especially with regard to capacity, conversion, and a simplified recycle, the advantages of the UNIPOL process, which yielded superior products and required only half the capital and a quarter of the energy, changed the entire focus to the new low-pressure process.

The process for high-density polyethylene was commercialized in 1968 and the process for low-density polyethylene was commercialized in 1975. Plant expansions based on the UNIPOL process of almost a billion pounds per year were announced in November of 1977—450 million pounds per year at Seadrift, Texas, and 500 million pounds per year at a new plant called Star, which was located immediately adjacent to the Taft Plant in Louisiana. Union Carbide was awarded another KIRKPATRICK CHEMICAL ENGINEERING ACHIEVEMENT AWARD in 1979 for development of the UNIPOL process. Dr. Karol was awarded the 1989 PERKIN MEDAL for his efforts on catalyst research

Successful application of the UNIPOL process to the polymerization of

polypropylene took place in 1982 in a cooperative development with the Shell Chemical Company. A joint venture with Shell was announced in 1983, and a Polypropylene Unit was built at Seadrift utilizing the new process. The new facility started up quickly and yielded high-quality products that encompassed a broader range than previously available.

The gas-phase UNIPOL process continued to lead the revolution in the polyethylene industry in the 1980s and 1990s with a new mode of operation (condensing) that increased reactor capacity by over fifty percent. Further enhancement in the 1990s permitted the manufacture of a complete range of low-density and high-density resins with controlled molecular weight and compositional distribution. The process was further extended successfully to the manufacture of vulcanizable ethylene-propylene rubbers. It was quite a show. In 1993, the President of the United States awarded the United States National Medal of Technology to Dr. William H. Joyce, President of Union Carbide Corporation, in recognition of his leadership in the development, commercialization, and success of the UNIPOL process.

Consistent with its past policy of not licensing core technologies, Union Carbide had not licensed its high-pressure polyethylene technology. However, inasmuch as the Company did not invest at a rate high enough to maintain market share, other producers were able to enter the market even though they did not have state-of-the-art technology. In the case of high-density polyethylene, a decision was made in the 1970s to license, because the Company did not have a dominant position in the market and because incremental income could be realized from the superior technology. As a result, licenses for the new high-density process were granted in the early 1970s to Czechoslovakia, the Soviet Union, and Gulf Chemical Company.

In 1977, as the full impact of the technological breakthroughs became evident, the Company elected to exploit the situation by aggressively licensing the low-pressure polyethylene process. (It was at this time that the term UNIPOL was coined to identify the new process.) The decision to license was done in light of the fact that potential earnings from both licensing and investing in new plant were projected to significantly exceed earnings from investing in new plant alone—especially inasmuch as the total new capacity projected was beyond the Company's ability to finance it. Licensing income was projected to be significant, because it was to be based on taking a share of the savings achieved by the licensee.

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As a result, a Licensing Department was established in 1977 and licensing discussions initiated with potential clients. The first UNIPOL license for low-density (and high-density) polyethylene was signed in 1979 with the Exxon Chemical Company. Exxon abandoned a mature polyethylene project to take on the new process. During the first five years of the licensing program, Union Carbide licensed more than fifty percent of all the new low-density polyethylene capacity in the world. By 1993, about ten million tons per year, half the world's low-density polyethylene capacity, was based on UNIPOL technology. (In one novel case, a 120,000 metric ton UNIPOL process plant was built in 1981 aboard a barge in Nagoya, Japan, for IPAKO, SA, of Argentina, and the barge taken aboard a ship, the Super Servant I, for a trip of 15,000 miles to Bahia Blanca in Argentina for docking and operation.)

Chemical Hygiene Fellowship

The Chemical Hygiene Fellowship (CHF) was formed in 1937 under a contract between the Mellon Institute in Pittsburgh and Union Carbide and Carbon Chemicals Corporation. The purpose of the Fellowship was to conduct "a study of the hygienic aspects of synthetic aliphatic compounds and of the materials and products of the companies affiliated with the donor with particular reference to their industrial applications." The major responsibility of the Fellowship was Union Carbide chemicals products. The aims of the Fellowship were to protect the safety of industrial production, transportation, and handling before information based on human experience had been accumulated. This included definition of safe handling procedures, protective equipment, and medical scrutiny of workers.

The Chemical Hygiene Fellowship operated as a service to the Marketing and Sales Departments from 1937 to 1962. After 1962, it was administered by the Chemicals and Plastics Research and Development Department. In the mid 1970s, the staff of the Chemical Hygiene Fellowship was doubled and a new facility constructed at Bushy Run, near Pittsburgh. In 1980, Union Carbide assumed management of the laboratory (from Mellon) and the name was changed to the Bushy Run Research Center.

The Chemical Hygiene Fellowship was a pioneer in the application of toxicology to product development at the outset. It was integrated step-by-step with the activities of chemists, engineers, and marketing experts. It was applied widely

to materials that would be successfully developed as well as to those that fell by the wayside. It required the standardization of toxicological methods and the development of procedures for deriving sound inferences from the results. Range-Finding Tests were developed for new products that are now generally accepted procedures by applied toxicologists. These included estimates of the hazards of swallowing, breathing, skin penetration, and skin and eye contact. These practices, originally voluntary, are now required by law. The Chemical Hygiene Fellowship also determined and published data on threshold limits of exposure. This resulted in a large collection of toxicological data, which had the advantage of providing experience with hundreds of substances others had never encountered and provided a base for predictions about new substances based on structure.

Results of the work done by the Fellowship were made available to the scientific community through publication and information sharing. The success of the Chemical Hygiene Fellowship was largely due to the wisdom, persistence and dedication of Drs. Henry F. Smyth, Jr. and Charles P. Carpenter. The laboratory was terminated in 1995 as demand decreased and alternate resources became available to industry at large.

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Chapter Seven
TRANSFORMATION (1980-1990)

The 1980s were the most turbulent years in the history of Union Carbide. There was solid growth in polyethylene and UNIPOL licensing (captive polyethylene capacity would grow to over three billion pounds per year by the early 1990s), there was solid growth in ethylene oxide/glycol (the Company was the world's largest producer by a factor of two), and there was growth in low-pressure oxo (LPO) manufacture and licensing (few oxo plants in the world had been built since 1979 other than with the Company's LPO process.) Two events, however, overshadowed everything else. One was the sabotage of the plant at Bhopal, India and the resulting disaster. The other was the attempted takeover and subsequent restructuring of the Company.

The decade started off reasonably well. First there was a move of the Corporate headquarters in 1981 from New York City to Danbury, Connecticut. The move was made in response to problems that many people were experiencing in commuting to mid-town Manhatten from the suburbs. Typically, commutes took an hour-and-a-half or more each way and were limiting to both business activities and personal lives. The prospect of long, time consuming commutes also made it increasingly difficult to get people to transfer to New York. The new location was suburban, almost rural, and very pleasant, and access to the new office was much easier. Plans also had been afoot in the late 1970s and early 1980s to refocus business efforts on more profitable endeavors. To that end, the sale of most of the metals business had been completed by 1981. Despite a persistent recession in 1981-1982, consolidated sales for the Corporation reached over $10 billion in 1981, and earnings were respectable.

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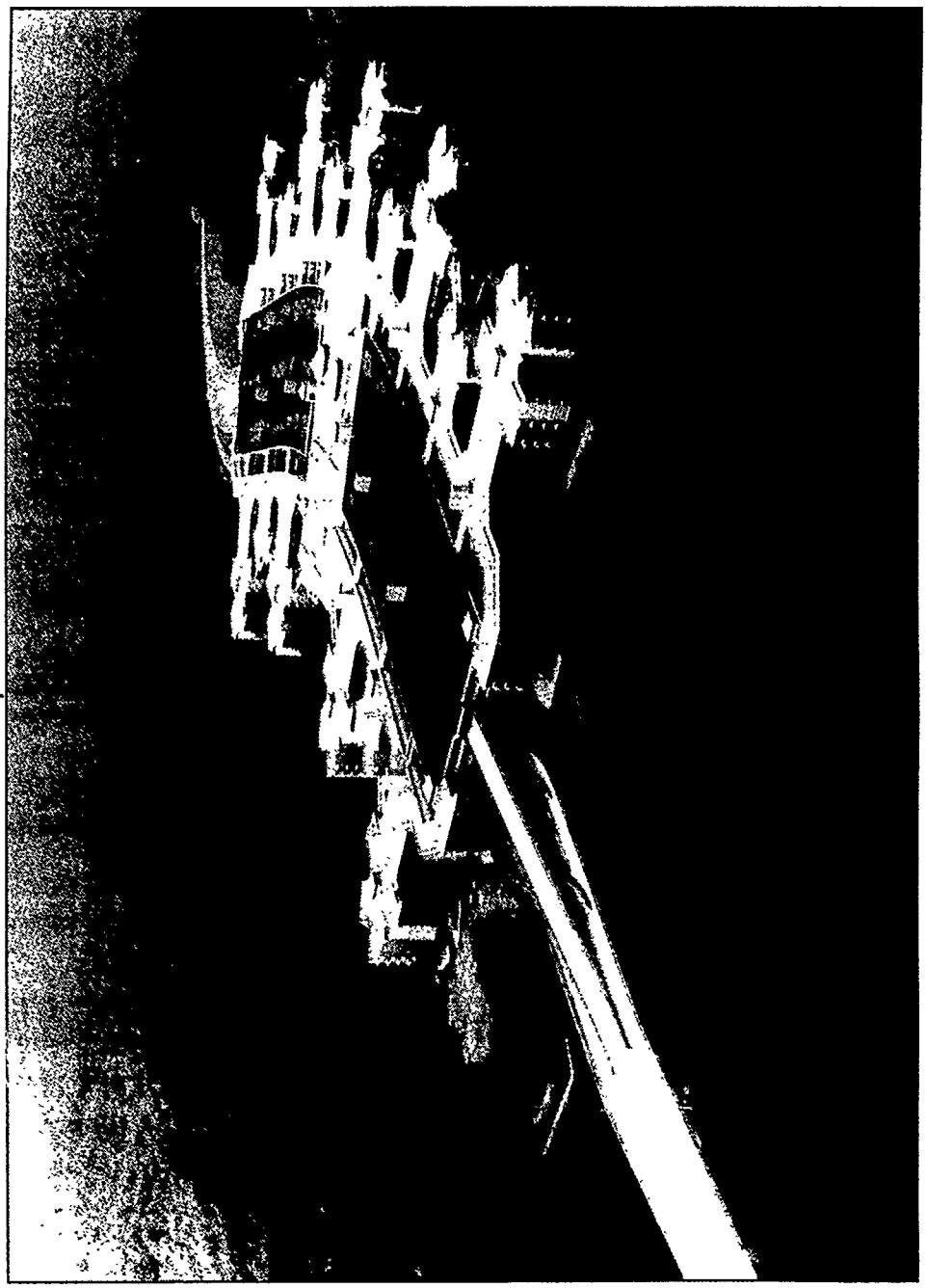


Figure XXVII
Union Carbide Corporate Offices at Danbury, CT (1981 - Present)

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Major Projects

Several major projects were completed and placed in service in 1983. One was the Canadian Prentiss Plant, near Red Deer, Alberta, a large, new, free-standing ethylene oxide-ethylene glycol plant based on purchased ethylene and built to serve the Asian export market. The initial capacity of the plant was 500 million pounds per year of glycol, which was later expanded to 660 million pounds per year. The product was shipped in dedicated unit trains from Red Deer to the port of Prince Rupert on the Pacific Coast for transfer to seagoing tankers. Despite severe weather conditions—it gets cold in Red Deer, the frost line is nine feet deep—the whole operation came off well. (A second ethylene oxide/glycol plant of similar size was built in the early 1990s at Prentiss as a joint venture with three Asian companies to yield a total capacity of 1.3 billion pounds per year of ethylene glycol.) Another project completed in 1983 was a major grass roots silicones plant in Termoli, Italy, that was built to serve the European market for silanes. This project was also successful. It was on schedule, within budget, and ran well. A third project was a new, 35,000-ton, multicompartmented tanker, the Chemical Pioneer, that was completed and delivered in September of 1983. The tanker, which could carry over nine million gallons of products, went into service transporting chemicals from the Taft and Texas City plants on the Gulf Coast to Eastern U. S. markets. It replaced two older, smaller tankers, one of which had been built during World War II. The new tanker was replete with tank cleaning devices and self-contained waste facilities.

The year 1984, however, was the start of a wild ride that would last for several years.

Silicones II

Problems started with a large new methylchlorosilanes plant, Silicones II, that was built in 1981-1982 at South Charleston on the site of the old No. 3 Olefins Unit. New processes were involved, and considerable difficulties were encountered in starting up the plant and operating it. Those problems, coupled with second thoughts about making a product that was essentially a commodity intermediate when the rest of the business was specialty chemicals, resulted in the plant being shutdown in 1984, dismantled, and written off. It was a major loss.

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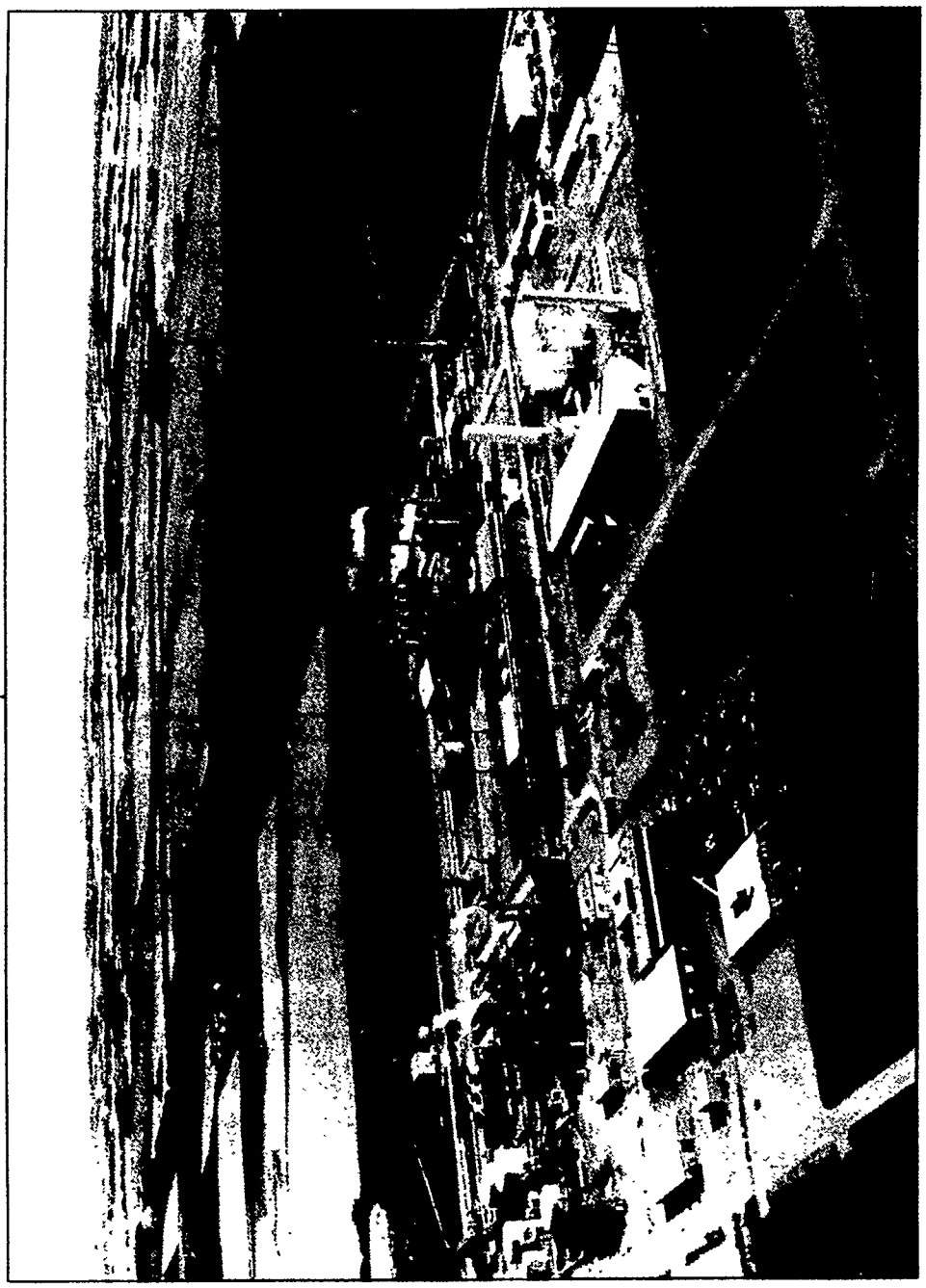


Figure XXVIII
Prentiss (Alberta) Plant in 1994

Bhopal

A massive tragedy struck in the early hours of December 3, 1984, at Union Carbide India's carbamate insecticide plant at Bhopal, India. Toxic gas was discharged into the atmosphere from a 15,000-gallon tank of methyl isocyanate and spread downwind in the darkness through squatters' huts and shanties located around the plant. Methyl isocyanate is an intermediate in the manufacture of the carbamate insecticide SEVIN. Several thousand people were killed and thousands more were injured—no one knows the actual number. Most of the people affected were very poor. (The plant had been built in an open field outside the town, and the squatters' settlement came later.)

The gas release came in darkness at a shift change and was an act of sabotage by a disgruntled employee who apparently sought to discredit his supervisor by ruining a tank of methyl isocyanate. (It is unlikely that he was aware that the consequences would be so terrible—his own parents lived nearby.) It was eventually determined that the employee had removed a pressure gage from a storage tank, connected a water hose to the tank at that point, and injected several hundred gallons of water into the tank. The water reacted with the methyl isocyante in the tank, overpressured the tank, and caused the release of toxic methyl isocyanate gas through an emergency relief system. The plant, which was being operated entirely by Indian nationals at the time, had been producing, using, and storing methyl isocyanate for five years without any problems.

As the tragedy unfolded, the first reaction at Union Carbide (as everywhere) was shock and horror. The second reaction was to provide direct and massive relief for the victims. This was in the form of medical services, a technical team, equipment, and money (nearly two million dollars) that were dispatched almost immediately to the site. Warren M. Anderson, the Chairman of the Board, also went immediately to the site. Anderson was not grandstanding, he hoped that his involvement would be beneficial. The Government of the State of Madyha Pradesh (in which Bhopal is located) rejected most of the aid and placed Anderson and the Chairman and the Managing Director of Union Carbide India Limited (UCIL) under arrest. Six other UCIL employees were also charged. Anderson subsequently was released from arrest and permitted to return to the United States. However, the charges against him were not dropped.

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After initially being barred from the site, members of the technical team were allowed in the plant for a couple of weeks, mostly to help safely convert the remaining methyl isocyanate to innocuous SEVIN. While there, however, they were also allowed to take samples from residues in the tank, which permitted the determination that the reaction had been caused by the injection of one or two thousands of pounds of water into the tank. After three weeks, the technical team was again excluded from the plant by the Government of India and would not be able to reenter it for over a year.

The Company also sent in an independent medical team to treat the victims and offered $5 million in aid with no strings attached. These funds were also rejected. (The money was then given to the Indian Red Cross.) Despite repeated assurances of "no strings attached," the Government of India continued to reject all relief that originated with Union Carbide, even if provided by a third party. For example, the Company designated $2.2 million for Arizona State University to build and operate a rehabilitation center in Bhopal. When the Government of India learned that Union Carbide had provided the funds, it bulldozed the center.

It was obvious that others' objectives were not relief for the victims, but rather, vilifying and punishing Union Carbide and extorting from it as much money as possible. The main players in this drama were the Government of India and American plaintiff lawyers. Despite the fact that India has a well-established court system that is based on similar principles to those in the United States, both the Government of India and the American plaintiff lawyers sought to bring class-action suits against the Company in the United States where the prospect of a rich payout was better. Bhopal has been called the "greatest ambulance chase" in history as American lawyers flocked to India within days and indiscriminately began signing up claimants for class-action suits. At one time in the city of 650,000 people, there were nearly 500,000 claimants. Most of the claims, of course, were spurious.

The Government of India sought to be the representative for the victims (rather than the American lawyers) and brought suit in Federal Court in New York. However, the U. S. Courts established that India was the proper venue for litigation. The Government of India therefore brought suit in India. They sought criminal charges against Union Carbide officials and claims of $3 billion. (American lawyers had been seeking $50 billion.)

The Company mounted an intense investigation that proceeded independently and in parallel with a Government of India investigation. The Company's investigation was difficult, because the government was uncooperative and because employees had been intimidated by local authorities and were reluctant to testify. Some UCIL employees were also anxious to hide any personal liability that they may have incurred in dealing with the emergency. Eventually, however, the facts were discerned and reported by Carbide. They were corroborated independently by Arthur D. Little, Inc., a highly reputable consulting firm from Cambridge, Massachusetts.

The suit against the Company was concluded in 1989. The Supreme Court of India directed a settlement of $470 million and nullification of the criminal charges. It was the largest award ever made in India and was described by the Court as "just, equitable, and reasonable." The Court also directed that the Government of India make payments to the victims. Union Carbide paid the $470 million promptly—within ten days of the Court decree. However, a new administration of the Government of India, encouraged by political activists, challenged the settlement and sought to reinstate the $3 billion claim and criminal charges against Union Carbide officials. In the process the victims were mostly ignored. Two years later, in 1991 the Indian Supreme Court upheld the original cash settlement and only then did substantial money start to flow to the victims. The criminal case was permitted to remain open.

Union Carbide closed out the Indian Agricultural Products business and sold the rest of its operations in India. (Owing to the outstanding criminal charges, Union Carbide still cannot have any direct participation in India despite its 70-year plus history as a good and useful citizen in India.) Union Carbide had owned only 50.9 percent of Union Carbide India Limited. About 25 percent of UCIL was owned by the Government of India and the rest was publicly held. The Company's proceeds of the sale of its stake in UCIL were pledged to a trust in London to build a hospital in Bhopal and to minister to the victims there. There is about $100 million in the trust.

There were several tragedies along the way at Bhopal. The first, of course, was the death and injury of so many people, for which Union Carbide accepted moral responsibility despite the fact that the event was an act of sabotage. The second was the neglect of aid for the victims by the Government of India. Aid took second priority to greed and politics. (There was considerable political unrest in

India at the time owing to the assassination earlier of Indira Ghandi, the Prime Minister.) A third tragedy was the loss of domestically produced SEVIN that had contributed to India's being self-sufficient in food. Inasmuch as the typical farm in India is only a couple of acres it is farmed largely by hand. SEVIN is an insecticide that can be applied safely without special equipment. Domestically produced SEVIN was also important because it was rupee-based and India lacks foreign exchange to import SEVIN

Union Carbide's reputation and collective psyche suffered greatly in the aftermath of Bhopal, "the worst industrial accident in history." The irony was that Union Carbide was a good corporate citizen and always had a high concern for the safety and health of its employees and others. It has also been a leader in industry programs in the pursuit of employee safety and health. Perhaps one good thing to come out of it all has been an increased awareness of risk and an increased emphasis on safety not only by Union Carbide, but also by the chemical industry as a whole. As noted in 1990 by Robert D. Kennedy, the Chairman of Union Carbide, the Company has accepted that "Bhopal has placed a special obligation on it to meet the highest standards for health, safety, and environmental excellence", and it has established programs to meet those standards.

Divestitures And Restructuring

As indicated earlier, the Company had begun to refocus its efforts on its stronger lines. It had started to divest areas that didn't fit, and by the early 1980s, almost a billion and a half dollars worth of businesses had been sold. In 1984, the Company also relinquished the operations of the nuclear facilities at Oak Ridge, Tennessee, and Paducah, Kentucky, to the Martin-Marietta Corporation. Carbide's involvement had lasted forty years and was no longer critical to national needs. The operation had been conducted for the Federal Government essentially as a civic endeavor and no profit was involved.

The process of "restructuring" was greatly accelerated by the events at Bhopal. Investors dumped Union Carbide stock in 1985 in anticipation of liabilities accruing to Bhopal, and the stock plunged to half its year earlier value. The stock already had been low and the reaction to Bhopal took it to less than half of its book value. Inasmuch as the Company was worth far more and coupled with the fact that it had a large, overfunded pension reserve (of about $1 billion), the Com-

pany became ripe for a takeover.

The attempt came in the fall of 1985. GAF, in the person of Samuel Heyman, a financier and Chief Executive Officer of GAF, made a hostile tender offer for the shares of Union Carbide. GAF, which at one time in the distant past had been General Aniline and Film, was only about one-tenth the size of Union Carbide, but it had the backing of Drexel Burnham, an investment banker with sufficient resources to make a leveraged buyout. Heyman's strategy was to take over Union Carbide, break it up, and sell the pieces at a substantial profit. With Carbide's low stock valuation, the pieces were far more valuable than the whole, even with the Bhopal liability, and the overfunded pension reserve would be icing on the cake.

The Company mounted a defense to the takeover attempt to preserve stock holder values, and a bidding war ensued. GAF made a final offer on Christmas day of 1985, but the Company topped it on January 2, 1986. The Company's offer to the stockholders included stock and a cash dividend of $33 a share, close to the mid-1985 market value of the stock. (The exchange mechanism consisted of making a three for one stock split and then buying back one of those three shares for $33.) The stockholders accepted this offer and the Company prevailed.

An immediate consequence of the huge cash dividend offer was that, in addition to taking on debt, parts of the Company had to be sold to pay the bill. The Consumer and Electronics businesses were selected for divestiture, because they had the highest growth and earnings quality, would be easiest to sell, would yield the most money, and would least impair the stockholders' remaining equity. Employees were advised of the situation and managers were brought in to participate in selling their units. A condition of each sale was that the purchaser had to commit to offering a position to every current employee at a salary and with benefits equal to what they were getting at Union Carbide.

Under these conditions, the Company, in 1986, divested Home and Automotive Products for $800 million to First Brands, Inc., Battery Products for $1.4 billion to Ralston Purina Corporation, and the Films Packaging Division for $215 million to Envirodyne. The Agricultural Products business was sold to Rhone-Poulenc, a French company, for $575 million. The remainder of the Metals Division, The Carbon Specialties group, and Kemet all went to leveraged buyouts, mostly by former employees. The cash generated by these divestitures exceeded the market value of the entire Corporation prior to the takeover attempt.

Not all the movement was downward. In 1988, the Company acquired a

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half interest in UOP (formerly Universal Oil Products) from the Allied-Signal Corporation in exchange, largely, for Union Carbide's molecular sieve business. UOP is a process and licensing business serving the process industries (chemicals and petroleum). Union Carbide's molecular sieve businesses of manufacturing and selling catalysts, adsorbants, and process systems was complementary to the UOP operations. UOP is thriving in the 1990s with sales of about one billion dollars per year.

Union Carbide was realigned as a holding company in 1989, forty years after being converted to an operating company, as a prelude to final restructuring. The companies under the holding company umbrella were Union Carbide Chemicals and Plastics, Union Carbide Industrial Gases (Linde), and UCAR Carbons (Carbon Products). Union Carbide Industrial Gases was spun off as Praxair in mid-1992 in a tax-free exchange for stockholders. (The name Praxair was adopted because the name Linde was usable only in the United States under terms of the original agreement with Professor von Linde. Praxair, which is the largest industrial gases company in the Western Hemisphere, could use its new name in pursuit of broadening its markets in the rest of the world.) Half of UCAR Carbons was sold to Mitsubishi Corporation in 1991, and then both Mitsubishi and Union Carbide sold out completely in 1995. The Organosilicones Division, which was not regarded as part of Union Carbide's core businesses, was sold in 1993 to OSI Specialties, Inc. With these divestitures, the last major steps in the restructuring of Union Carbide were complete. The Company had an entirely new identity, no longer a conglomerate, but instead a basic, intermediates, and specialty chemicals company. The focus now was on being the best in its field. Its strategy was to be "a uniquely advantaged global chemical company recognized as the low-cost, preferred supplier in its core businesses."

The two men who led Union Carbide through these extremely difficult years were Warren M. Anderson and Robert D. Kennedy. Anderson served as chairman of the board from 1981 to 1985. Kennedy was chairman of the board from 1986 to 1995. Anderson had to cope with the Bhopal crisis. He acted constructively, ethically, humanely, and with grace while under great pressure and sometimes in the face of hostility. Kennedy guided the restructuring of the Company. He did it in a clear headed fashion that was effective and as fair as possible to both the employees affected and the shareholders involved. Kennedy also was one of the leaders in the implementation of the industry-wide "Responsible Care" program—a code of

mandatory management practice to ensure safeguards for employees, users, transporters, and the public throughout the life cycle of a company's products.

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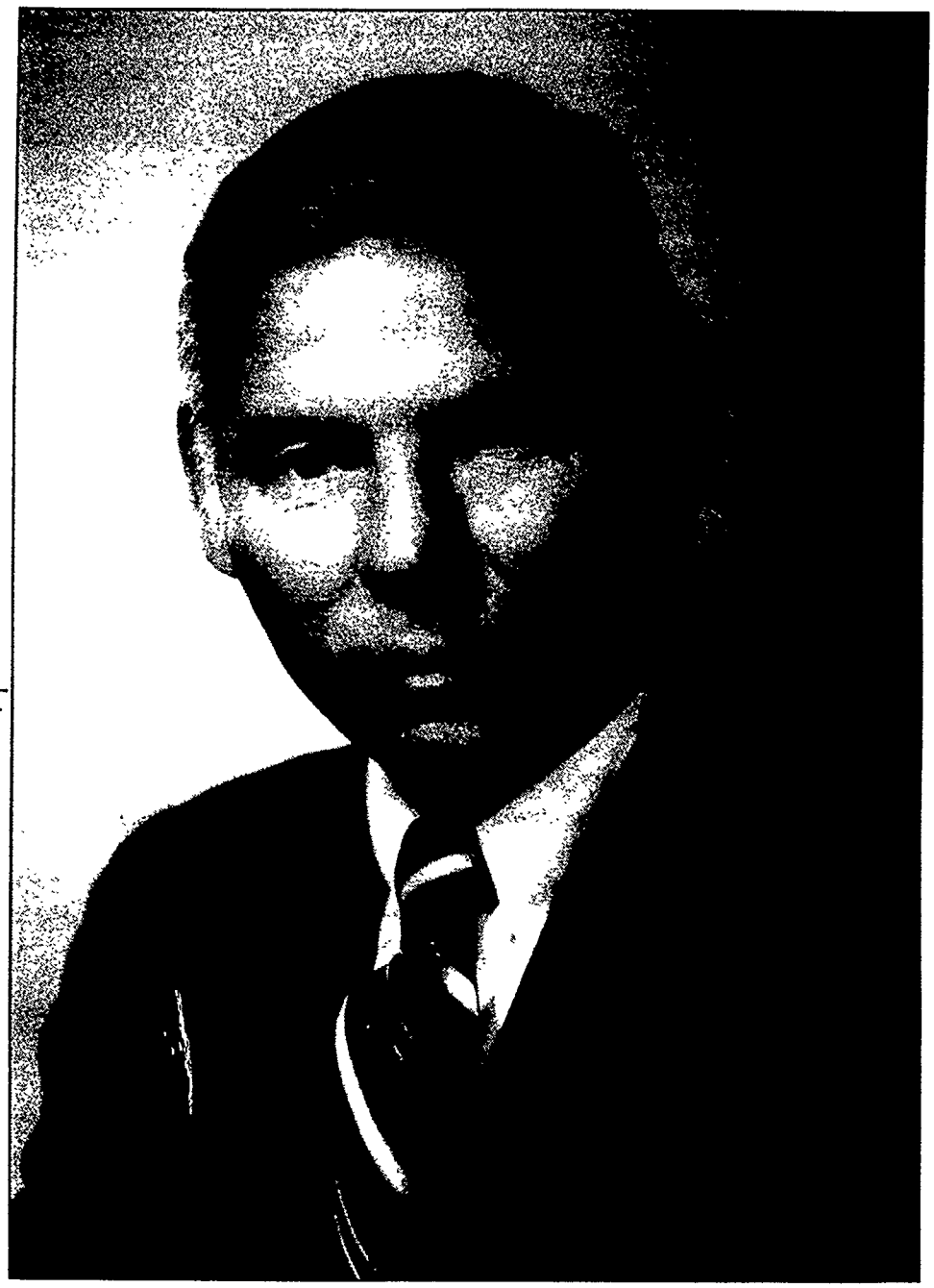


Figure XXIX
Warren M. Anderson

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Figure XXX
Robert D. Kennedy

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Epilog

Over the years, Union Carbide and its people made substantial contributions to technology, business, and society. The Company was a very special place for those associated with it: the mood was civil, the corporate character was ethical, there were many capable people, and things were happening. There was a strong sense of belonging—of being a "Carbider"—which existed pretty much at all levels and across the entire Organization.

Success sometimes seems to be measured by size, the bigger the better. Union Carbide ended up by being smaller, and some have viewed the Company negatively from that standpoint. (Net Corporate sales in 1990 were $7.6 billion—including Industrial Gases (Linde)—and $6.1 billion in 1996 without Industrial Gases and Osi (Silicones)—compared to peak Corporate sales of $10.2 billion in 1981). However, the situation must be considered more broadly. The Company today is stronger, more focused, and growing. Most of the parts divested are also stronger and thriving, and in the process, value was created. In that light, despite the pains of passage, the aggregate outcome must be regarded as positive.

Another chapter of Union Carbide's history remains to be written—that of the 1990s with the story of "re-engineering" and the outcomes of the new business focus and the new technologies. We'll leave that for someone else to do in the future.

RDS

January 1998

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About the Author



The author, Robert D. Stief, came to chronicle the history of Union Carbide Corporation in a roundabout way. He had suggested in 1993 to Union Carbide that it participate in the Chemical Heritage Foundation's recording of the history of the chemical industry in America. In turn, he was asked if he would do it himself under the aegis of the Carbide Retiree Corps—to which he agreed. The timing was probably propitious. If the work had been done any later, much of the earlier history would have been lost in the mists of time. If the work had been done very much earlier, the outcome of the transformation of the Company would not have been known. There turned out to be considerably more work than expected. It took five years to do instead of the two or three anticipated, and several hundred people participated in one way or another.

The author is a former director of engineering of the Chemicals and Plastics division of Union Carbide. He started work with the Company in 1952 at South Charleston, West Virginia, and was associated with the Engineering Department for his entire career with the Company except for a two-year stint as an employee relations manager. Prior to joining Union Carbide, he was in the U.S. Army Air Force (1944 - 1945) and at Los Alamos Scientific Laboratory (1951 - 1952). He has bachelor's and master's degrees in Chemical Engineering from the University of New Mexico and Syracuse University, respectively, and is a Fellow in the American Institute of Chemical Engineers. His avocation is anthropology. He retired from Union Carbide in 1983 and now lives at Seabrook Island, near Charleston, South Carolina.

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APPENDIX

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Products and Services – Current

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PRODUCTS AND SERVICES

1940

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Annual Report

of

UNION CARBIDE AND CARBON CORPORATION

1940

Principal Units

ACHESON GRAPHITE CORPORATION
AKTIESELSKABET MERAKER SMELTEVERK
AKTIESELSKABET SAUDEFALDENE
AMERICAN CARBOLITE COMPANY, INC.
BAKELITE CORPORATION
CANADIAN NATIONAL CARBON COMPANY, LIMITED
CARBIDE AND CARBON CHEMICALS CORPORATION
CARBIDE AND CARBON CHEMICALS LIMITED
CARBIDE AND CARBON REALTY COMPANY, INC.
DOMINION OXYGEN COMPANY, LIMITED
ELECTRIC FURNACE PRODUCTS COMPANY, LIMITED
ELECTRO METALLURGICAL COMPANY
ELECTRO METALLURGICAL COMPANY OF CANADA, LIMITED
ELECTRO METALLURGICAL SALES CORPORATION
HAYNES STELLITE COMPANY
KEMET LABORATORIES COMPANY, INC.
THE LINDE AIR PRODUCTS COMPANY
MICHIGAN NORTHERN POWER COMPANY
NATIONAL CARBON COMPANY, INC.
OXWELD ACETYLENE COMPANY
THE OXWELD RAILROAD SERVICE COMPANY
THE PREST-O-LITE COMPANY, INC.
PREST-O-LITE COMPANY OF CANADA, LIMITED
UNION CARBIDE COMPANY
UNION CARBIDE COMPANY OF CANADA, LIMITED
UNION CARBIDE AND CARBON RESEARCH LABORATORIES, INC.
UNITED STATES VANADIUM CORPORATION

Condensed Summary of Products

The products and processes of the Corporation, summarized in the following pages, may be grouped into four divisions:

ALLOYS AND METALS

Ferro-Alloys and Refined Alloying Metals
Metals and Alloys for Abrasion-Resistance and for Corrosion-Resistance

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CALCIUM CARBIDE AND GASES

Calcium Carbide
Oxygen, Nitrogen, Rare Gases of the Atmosphere
Acetylene and Hydrogen
Welding and Cutting Apparatus and Supplies
Steel-Conditioning Machines and Processes
"Unionmelt" Welding Process and Equipment

•

ELECTRODES, CARBONS, AND BATTERIES

Carbon and Graphite Furnace Electrodes
Graphite Anodes for Electrochemical Processes
Carbon, Graphite, and Metal-Graphite Brushes
Carbon, Graphite, and "Karbate" Structural Materials
Projector and Photographic Carbons
Flashlights and Batteries
Dry Cells and Radio Batteries
Anti-Freezes and Insect-Repellent Lotions

•

SYNTHETIC ORGANIC CHEMICALS AND PLASTICS

Alcohols, Glycols, and Alcohol-Ethers
Aldehydes, Ketones, Acids, Anhydrides, and Amines
Ethers, Oxides, Esters, and Chlorinated Compounds
Anti-Freezes, Hydrocarbon Gases
Plastics, Resins, and Waxes

Reprinted from the Union Carbide and Carbon Corporation Annual Report of 1940.

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Alloys and Metals Division

Alloys of chromium, manganese, silicon, vanadium, columbium, and tungsten impart properties to steel which have made possible revolutionary changes in many industries. In every form of transportation, lighter weight construction with greater speed and safety is the result of the use of alloy steels. Resistance to corrosion and oxidation of special metals such as stainless steel has brought numerous improvements and economies in the oil, food, chemical, paper, and textile industries. In mining, machinery and parts made of alloy steels give greater life because of their resistance to corrosion and abrasion. The ALLOYS AND METALS division of the Corporation manufactures and sells these alloys in different forms, and promotes the use of stainless steel and other alloy steels in industry.

The ALLOYS AND METALS division of the Corporation includes Electro Metallurgical Company; Electro Metallurgical Company of Canada, Limited; Electro Metallurgical Sales Corporation; Haynes Stellite Company; Kemet Laboratories Company, Inc.; United States Vanadium Corporation; Aktieselskabet Saudefaldene; Aktieselskabet Meraker Smelteverk; and Electric Furnace Products Company, Limited.

FERRO-ALLOYS AND METALS—*Brand name is "Electromet."*

CALCIUM—*Calcium-Aluminum-Silicon, Calcium-Manganese-Silicon, Calcium Metal, and Calcium-Silicon.*

Combination alloys of calcium and silicon are extremely efficient deoxidizers and purifiers in the manufacture of steel and high-strength cast iron.

CHROMIUM—*Chromium Briquets, Chromium-Copper, Chromium Metal, CMSZ Alloy, and Ferrochromium (Ferrochrome).—Brand name for briquets is "EM."*

Chromium is the principal alloying element in stainless steels. Ferrochromium imparts strength, hardness, and resistance to

TRADE-MARKED PRODUCTS INCLUDE

Electromet
Ferro-Alloys & Metals

corrosion and oxidation. High-nitrogen ferrochromium is particularly effective in reducing grain size and improving the physical properties of steels containing 20 per cent or more chromium. Chromium prevents growth, and increases the strength and hardness of cast iron.

COLUMBIUM—*Ferrocolumbium.*

Columbium is used in the manufacture of stainless steels. It imparts improved welding characteristics to these steels and makes them particularly suitable for high-temperature applications.

MANGANESE—*Standard Ferromanganese, Low- and Medium-Carbon Ferromanganese, Ferromanganese-Silicon, Manganese Briquets, Manganese-Copper, Manganese Metal, and Silico-Manganese.—Brand name for briquets is "EM."*

Manganese is an essential element in the manufacture of nearly all grades of steel. It improves hot-rolling properties, adds strength and toughness, and is generally used as a deoxidizer. Low-carbon ferromanganese is used in stainless steel to impart better hot ductility and to improve weldability. Medium-carbon ferromanganese is used in low-carbon sheet steel to prevent age-hardening. Silico-manganese alloys hasten the refining of quality steels, reduce impurities and surface defects, and improve rolling properties.

SILICON—*Ferrosilicon, Silicon Briquets, Silicon Metal, and SMZ Alloy. —Brand name for briquets is "EM."*

Silicon is extensively used for degasifying and deoxidizing steel and cast iron. It imparts special electrical properties to steel, and is also used for the generation of hydrogen. SMZ alloy is a combination of silicon, manganese, and zirconium effectively used for softening cast iron. Silicon, manganese, and chromium are alloyed in non-ferrous metals, such as aluminum, nickel, and copper, to increase strength and improve other physical properties.

TRADE-MARKED PRODUCTS INCLUDE

EM CHROMIUM BRIQUETS EM MANGANESE BRIQUETS EM SILICON BRIQUETS

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TUNGSTEN—*Ferrotungsten, and other Tungsten Alloys.*

Tungsten adds hardness and strength to steels and is used in the manufacture of high-speed tool steels, tungsten magnet steels, and in "Haynes Stellite" and "Haystellite" alloys.

VANADIUM—*Ammonium Meta-Vanadate, Ferrovanadium, and Vanadium Oxide.*

Vanadium in alloy steels increases their strength and resistance to fatigue.

ZIRCONIUM—*Aluminum-Zirconium, Nickel-Zirconium, 35-40% Zirconium Alloy, 12-15% Zirconium Alloy.*

Zirconium alloys are active deoxidizers used in the manufacture of ferrous and non-ferrous metals. Zirconium combines with nitrogen and is used effectively in straight-chromium steels. It inhibits age-hardening in low-carbon sheet steel.

SPECIAL ALLOYS

ABRASION- AND CORROSION-RESISTANT ALLOYS—*Brand names are "Haynes Stellite," "Haystellite," "Hascrome," "Hastelloy," and "Stellite."*

"Haynes Stellite" non-ferrous alloys of cobalt, chromium, and tungsten are used for metal-cutting tools, and in the form of welding rod for hard-facing metal parts subject to abrasive wear, such as automotive and steam valves, agricultural implements, and cement and steel mill equipment. The outstanding characteristic of these "Haynes Stellite" alloys is that they will remain hard when red hot. This is known as "red hardness"; it makes "Haynes Stellite" alloys particularly adaptable for high-speed metal-cutting tools and for resistance to abrasion.

"Haynes Stellite" "93" alloy is an iron-base alloy containing cobalt, chromium, molybdenum, and vanadium, used in the form of welding rod for hard-facing metal parts subjected to severe abrasion with only a moderate amount of impact. This alloy is also made as special wear-resistant castings.

TRADE-MARKED PRODUCTS INCLUDE

HASTELLOY — CORROSION-RESISTANT ALLOYS

HAYNES STELLITE — HAYSTELLITE — ABRASION-RESISTANT ALLOYS

HASCROME — IMPACT-RESISTANT ALLOY

"Haystellite" cast tungsten carbide is an extremely hard material used in the form of inserts, composite rod, and tube rod for increasing the life and efficiency of oil well drilling and coring tools, and other metal parts subjected to severe abrasion.

"Hascrome" high-iron hard-facing rod, containing chromium and manganese, is used for surfacing wearing parts subjected to heavy shock or impact.

"Hastelloy" ferrous and non-ferrous alloys are used in the form of castings and fabricated equipment to handle acids and severely corrosive chemicals.

BARIUM GETTERS—*Brand name is "Kemet."*

These are used for the removal of gas from radio tubes.

Calcium Carbide and Gases Division

The products of this division are used principally for the welding and cutting of metals. These products include oxygen, calcium carbide, dissolved acetylene, and many types of automatic and hand-operated equipment.

The oxy-acetylene process is used in practically every manufacturing industry—particularly in the steel producing, metal fabricating, and metal consuming industries. Typical uses are the welding of various metals, including special steels and alloys, in production and repair; welding of pipe joints for oil, gas, water, and steam lines; building-up of worn rail ends; production cutting of steel shapes; cutting of scrap metal; conditioning of steel during its manufacture; and the flame-hardening and flame-softening of metals.

The CALCIUM CARBIDE AND GASES division of the Corporation includes The Linde Air Products Company; Dominion Oxygen Company, Limited; Michigan Northern Power Company; Oxweld Acetylene Company; The Oxweld Railroad Service Company; The Prest-O-Lite Company, Inc.; Prest-O-Lite Company of Canada, Limited; Union Carbide Company; and Union Carbide Company of Canada, Limited.

TRADE-MARKED PRODUCTS INCLUDE

UNION CARBIDE — CALCIUM CARBIDE

LINDE U.S.P. OXYGEN

Prest-O-Lite — DISSOLVED ACETYLENE

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ACETYLENE—*Brand name is "Prest-O-Lite."*

The basic materials for the oxy-acetylene process of welding and cutting metals are oxygen and acetylene. "Prest-O-Lite" dissolved acetylene is furnished through numerous plants and warehouses in large cylinders for welding and cutting, and in small tanks for motor truck lighting, soldering, brazing, and heating.

CALCIUM CARBIDE —*Brand names are "Union" (packed in the well-known blue and gray drums), "Cameo," "Carbic," "Carbolite," "Imperial," and "Amazon."*

Calcium carbide is an electric furnace product from which is derived acetylene gas, used in the oxy-acetylene process of welding and cutting; in the production of dissolved acetylene; for farm and mine lighting; and as a basic material in the manufacture of various chemicals by chemical synthesis.

Calcium carbide in briquetted form is sold under the trademark "Carbic" for use chiefly in flood lights, and in portable acetylene generators for oxy-acetylene welding and cutting. "Carbic" flood lights are used on highways and railroads in night construction and repair work, in routine and emergency work throughout industry, and by municipal street and fire departments.

OXYGEN—*Brand names are "Linde," "Driox," and "Dominion" (in Canada).*

Oxygen is produced for use in the oxy-acetylene process of welding and cutting, for oxygen therapy, and for numerous other purposes. "Linde" oxygen plants and warehouses are located in all important industrial centers. Linde "Driox" liquid oxygen is supplied to large industrial users.

STEEL-CONDITIONING MACHINES AND PROCESSES—*Brand names are "Lin-de-Surfacer" and "Linde."*

Processes and machines developed for the mechanized oxy-acetylene conditioning of steel have greatly improved certain phases of steel mill practice. The "Lin-de-Surfacer" Conditioning

TRADE-MARKED PRODUCTS INCLUDE

DRIOX
LIQUID OXYGEN

LIN-DE-SURFACER
STEEL-CONDITIONING MACHINE

LINDE
RARE GASES

Machine removes defective surfaces from hot steel as a part of the continuous rolling process. The "Linde" Surface Remover conditions semi-finished steel where it is impracticable to perform this operation during the rolling process.

"UNIONMELT" WELDING PROCESS—*Brand name is "Unionmelt."*

The "Unionmelt" welding process, together with the necessary equipment and supplies, provides an automatic electric welding method which permits steel of commercially used thickness to be welded in one pass at remarkably high speeds. It produces welds of high strength and exceptional uniformity at lower costs than by former methods. Important applications are in the manufacture of ships, barges, railway cars and locomotives, large pipe, tanks, pressure vessels, and structural shapes.

WELDING AND CUTTING APPARATUS—*Brand names include "Oxweld," "Prest-O-Weld," "Purox," and "Carbic."*

A complete line of oxy-acetylene equipment, including welding and cutting machines, as well as blowpipes, regulators, acetylene generators, welding rods and supplies, is manufactured for use in the application of the oxy-acetylene process of welding and cutting. Flood lights and air-acetylene lighting and heating apparatus also are produced.

HYDROGEN—*Brand names are "Linde," and "Dominion" (in Canada).*

Hydrogen is used for the hydrogenation of oils and fats, for the production of metals from metallic oxides, and to furnish a non-oxidizing atmosphere for the heat-treatment of metals.

NITROGEN—*Brand names are "Linde," and "Dominion" (in Canada).*

Nitrogen, obtained from the atmosphere, is used in the incandescent lamp industry and wherever an inert atmosphere free of oxygen is desired.

RARE GASES —*Argon, Helium, Krypton, Neon, and Xenon.—Brand name is "Linde."*

Rare gases are extracted from air by the "Linde" Liquefaction

TRADE-MARKED PRODUCTS INCLUDE

UNIONMELT
ELECTRIC WELDING EQUIPMENT

Oxweld PREST-O-WELD PUROX
OXY-ACETYLENE WELDING AND CUTTING APPARATUS

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Process. They are used in the manufacture of luminous tube signs of all colors, and for scientific purposes.

VALVES, CYLINDERS, AND SPECIAL DEVICES

Cylinder Valves—*Brand name "McKay."*
Cylinders for refrigerant gases—*Brand name "Polco."*
All-metal containers for liquefied gases—*Brand name "Purox."*
Halide Leak Detector—*Brand name "Prest-O-Lite."*

Electrodes, Carbons, and Batteries Division

The operations of this division include the manufacture and sale of products made partly or entirely from carbon, and the merchandising of many consumer products made by other divisions.

Sales to industry include carbon and graphite electrodes, used in large quantities in electric furnaces for the production of steel, ferro-alloys, calcium carbide, phosphorus, and non-ferrous metals; and graphite anodes, used extensively for the production of chlorine and other electrochemical products. Other products sold to various industries include carbons for motion picture projection and photography; carbons for electric welding; carbon brushes for electric motors and generators; and an increasingly wide range of carbon specialties, particularly for anti-corrosion applications.

Products purchased by the consuming public include "Eveready" flashlights, flashlight batteries, radio batteries, "Air Cell" batteries, 6-inch dry cells, "Prestone" anti-freeze, "Trek" anti-freeze, and "Sta-Way" insect repellent lotion.

The ELECTRODES, CARBONS, AND BATTERIES division of the Corporation includes Acheson Graphite Corporation; Canadian National Carbon Company, Limited; and National Carbon Company, Inc.

ACTIVATED CARBON—*Brand name is "Columbia."*

Activated carbon is used for solvent recovery in industrial processes, and in gas masks for military and industrial purposes. It is marketed by Carbide and Carbon Chemicals Corporation.

TRADE-MARKED PRODUCTS INCLUDE

PRESTONE ANTI-FREEZE — EVEREADY BATTERIES, DRY CELLS, AND FLASHLIGHTS — Trek ANTI-FREEZE

ANTI-FREEZES AND CORROSION PREVENTIVE—*Brand names are "Eveready," "Prestone," "Trek," and "Rustone."*

"Prestone" anti-freeze, "Trek" anti-freeze, and "Rustone" corrosion preventive, described with the products of the SYNTHETIC ORGANIC CHEMICALS AND PLASTICS division, are marketed with other "Eveready" products by National Carbon Company, Inc.

"Prestone" anti-freeze is the leading brand. Used according to directions, "one shot" of "Prestone" anti-freeze is guaranteed to protect the cooling system of a car against freezing, and against clogging from rust formation, for an entire winter.

BATTERIES AND DRY CELLS—*Telephone and Ignition Dry Cells, Signal Cells, Flashlight Batteries, and Radio "A," "B," and "C" Batteries.—Brand names include "Eveready," "Air Cell," "Columbia," "Hot Shot," "Ignitor," "Layer-Bilt," "Super-Layer-Bilt," and "Mini-Max."*

Various kinds of primary batteries are manufactured. The original and basic product is the 6-inch dry cell, used for ignition, telephones, signal bells and buzzers, animated displays, and for numerous other purposes. Flashlight batteries are another familiar form of the dry cell.

"B" and "C" radio batteries, and some "A" radio batteries, use assemblies of miniature dry cells, packed and connected together. In "Layer-Bilt" batteries, the traditional cylindrical form of the dry cell has been changed to a flat layer, packed layer on layer to eliminate waste space and much internal wiring. The latest form is the new "Mini-Max" "B" battery for portable sets which gives approximately twice the service life of other batteries of equal size and is an important contribution to the development of smaller and lighter radios.

The "Air Cell" battery is a "wet" battery designed to supply "A" power for battery-operated radio sets.

TRADE-MARKED PRODUCTS INCLUDE

COLUMBIA DRY CELLS — LAYER-BILT RADIO BATTERIES — National CARBON BRUSHES — MINI-MAX "B" BATTERY — AIR CELL "A" BATTERY

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BRUSHES AND ELECTRICAL SPECIALTIES—*Brushes for Electric Motors and Generators, Welding Carbon Products, and Contacts.—Brand names include "Columbia," "National," "Pyramid," and "Corliss."*

Carbon, graphite, and metal-graphite brushes play an important part in the generation and use of electric power. They are manufactured in a wide range of sizes. Carbon specialties are used in welding and in numerous electrical applications.

ELECTRODES—*Carbon and Graphite.—Brand names are "National" and "Acheson."*

Electrodes are essential in arc-type electric furnaces used for the production of calcium carbide, ferro-alloys, phosphorus, alloy steels, non-ferrous metals, and gray iron. Carbon electrodes are made in sizes ranging from tiny battery carbons only 1/16 inch in diameter to huge 40-inch diameter furnace electrodes weighing several tons each. Graphite electrodes are also made in a wide range of sizes.

FLASHLIGHTS—*Brand name is "Eveready."*

Flashlights include a wide variety of types and sizes, ranging from small pocket lights to large powerful focusing searchlights and special types for industrial applications.

GRAPHITE PRODUCTS—*Anodes, Powders, Plates, Rods, and Tubes.—Brand names are "Acheson" and "National."*

Graphite anodes are used in electrolytic cells for the production of chlorine, caustic soda, and many other products. Graphite powder is used in the manufacture of dry batteries, brake linings, and lubricants.

INDUSTRIAL AND SOLARIUM ARC LAMPS—*Brand name is "National."*

Industrial arc lamps are used by industries requiring sources of light with special characteristics, and for the irradiation of milk and other foodstuffs. Large solarium arc lamps are used in hospitals for light therapy.

TRADE-MARKED PRODUCTS INCLUDE

KARBATE STRUCTURAL MATERIALS · STA-WAY INSECT REPELLENT · National LIGHTING CARBONS

INSECT REPELLENT LOTION—*Brand name is "Sta-Way."*

"Sta-Way" insect repellent lotion effectively repels mosquitoes, flies, and other winged insects. It is harmless to the skin and has a pleasant odor.

LIGHTING CARBONS—*for Carbon Arc Lights, Industrial and Medical Irradiation, and Motion Picture Projection and Photography. —Brand name is "National."*

The carbon arc is the most powerful artificial light source. Carbon arc searchlights are used by the Army and Navy. Modern motion picture photography and projection are made possible through carbon arc light.

MAZDA MINIATURE LAMPS—*Brand name is "Eveready."*

Mazda miniature lamps include a complete line for automobiles, toys, flashlights, and other uses.

STRUCTURAL SPECIALTIES—*for Corrosion-Resistant Plant Structures and Equipment.—Brand names are "Karbate," "Kempruf," "Carbocell," and "Graphicell."*

Carbon and graphite in the form of large beams, bricks, and pipe are used in constructing such equipment as electrostatic precipitators, heat exchangers, and fractionating columns. Where imperviousness to passage of gases or liquids is required, the graphite or carbon base material is rendered impervious through special treatment. Very porous types of material are used for filtering.

Synthetic Organic Chemicals and Plastics Division

In recent years, processes and reactions have been developed through research—sponsored largely by Units of the Corporation—which permit the building-up of desired organic compounds from chemical elements or from simpler compounds. This is called synthesis—and the products are known as synthetic organic chemicals.

TRADE-MARKED PRODUCTS INCLUDE

SYNASOL PROPRIETARY SOLVENT · CELLOSOLVE SOLVENT · CARBITOL SOLVENT

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These products are utilized by widely diversified industries, sometimes to replace chemicals with less desirable characteristics, but more frequently in connection with new processes based upon distinctive properties of the new compounds. They are used in the textile (including rayon), surface coatings, automotive, chemical, pharmaceutical, paper, petroleum, photographic, printing, rubber, explosives, plastics, and many other industries.

In addition to the industries for which they are essential raw materials, synthetic organic chemicals are also utilized as emulsifying agents in cosmetic creams, polishes, and shampoos; as wetting agents for speeding aqueous processes; as plasticizers for resins, gelatin glue, and adhesives; as anti-freeze compounds for cooling systems; as heat-transfer mediums for aircraft engines; and as synthetic resins used for high-test safety glass, plastic articles, adhesives, and synthetic fibers.

The SYNTHETIC ORGANIC CHEMICALS AND PLASTICS division of the Corporation includes Bakelite Corporation; Carbide and Carbon Chemicals Corporation; and Carbide and Carbon Chemicals Limited.

ACIDS AND ANHYDRIDES—*Acetic, Propionic, Butyric, Maleic, and "Carbic" Anhydrides; Butyric, Ethylbutyric, Caproic, and Ethylhexoic Acids. —Brand name is "Carbic."*

Organic acids and anhydrides are important raw materials in the manufacture of cellulose esters for rayon, safety photographic film, and plastics, and of certain perfume and flavoring essences. Acetic Anhydride is used also in making aspirin and other pharmaceuticals.

ACTIVATED CARBON—*Brand name is "Columbia."*

"Columbia" activated carbon, a product of the ELECTRODES, CARBONS, AND BATTERIES division, is marketed by Carbide and Carbon Chemicals Corporation. This material, which is available in several types and grades, is now universally used in both military and industrial gas masks, and is widely used in many commercial operations, such as the recovery of solvents vaporized into the air in industrial processes, and the removal of

TRADE-MARKED PRODUCTS INCLUDE

SOLVATONE SOLVENT

CARBIC ANHYDRIDES

COLUMBIA ACTIVATED CARBON

odors and other impurities from air and other gases. Complete plants for solvent recovery by the "Columbia" activated carbon system also are designed and supplied.

ALCOHOLS—*Methyl, Ethyl, Isopropyl, Butyl, Methyl Amyl, Ethylbutyl, Hexyl, Ethylhexyl, and higher Alcohols.—Brand name for a proprietary solvent is "Synasol."*

Alcohols are used in anti-freeze compounds and as solvents in the manufacture of lacquers, dyestuffs, artificial leather, and shellac solutions. They are components of drugs, food preparations, extracts, cosmetics and toilet preparations, antiseptics, and disinfectants. They are also converted into synthetic resins, rubber chemicals, and textile dyeing compounds.

ALCOHOL-ETHERS—*Methyl "Cellosolve," "Cellosolve," Butyl "Cellosolve," Phenyl "Cellosolve"; Methyl "Carbitol," "Carbitol," Butyl "Carbitol."—Brand names are "Carbitol" and "Cellosolve."*

"Cellosolve" and "Carbitol" solvents are used in lacquers, wood stains, hydraulic brake fluids, printing and dyeing of textiles, and in the manufacture of non-shatterable glass, and cosmetics.

ALDEHYDES—*Butyl, Croton, Ethylbutyl, Hexyl, and Ethylhexyl Aldehydes.*

Aldehydes are important in the manufacture of plastics and compounds used to accelerate the vulcanization of rubber.

AMINES—*Acetoacetanilides, Ethanolamines, Ethylene Amines, Isopropanolamines, Morpholine, Ethylhexyl Amines, Phenyl Ethanolamines.*

Most of the amines form soaps used as emulsifying agents in polishes, insecticides, cosmetics, and cutting oils, as well as in textile and leather treating compounds. They are also used in making dyestuffs, pigments, pharmaceuticals, and cement and rubber chemicals. Certain amines are used to remove or concentrate carbon dioxide and other acid gases.

TRADE-MARKED PRODUCTS INCLUDE

PRESTONE **WINTER-FLO** **BLUE-FLO** **Trek**
ANTI-FREEZES FOR WINTER PROTECTION

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ANTI-FREEZES AND CORROSION PREVENTIVE—*Brand names for anti-freezes are "Eveready," "Prestone," "Blue-Flo," "Trek," and "Winter-Flo," and for corrosion preventive, "Rustone."*

"Prestone" anti-freeze is the leading all-winter brand, and like "Trek" anti-freeze, it is marketed by National Carbon Company, Inc. "Trek" and "Winter-Flo" anti-freezes are concentrated methanol, effectively inhibited to retard corrosion. "Blue-Flo" anti-freeze is an ethyl alcohol base proprietary anti-freeze. Anti-freeze compounds also are manufactured for a number of national distributors who sell the materials under their own brand names.

"Rustone" corrosion preventive, added to the water in a clean cooling system, will retard the formation of rust.

CARBON DIOXIDE

Carbon dioxide is produced for the manufacture of "Dry Ice."

CHLORINATED COMPOUNDS—*Ethylene and Propylene Chlorhydrins; Ethylene, Propylene, and Triglycol Dichlorides; Trichlorethylene.*

The chlorinated hydrocarbons are characterized by high solvent power and are used in dry cleaning machines; in textile scouring; in the degreasing of metal parts; and for the extraction of oils, fats, and waxes. Ethylene Dichloride is one of the solvents for tetraethyl lead used to increase the octane rating of gasoline. When mixed with carbon tetrachloride, it is also widely used as a fumigant for insect pests.

ESTERS—*Methyl, Ethyl, Isopropyl, Butyl, Methyl Amyl, and Ethylhexyl Acetates; "Carbitol" and "Cellosolve" Acetates; Dimethyl and Dibutyl Phthalates; Diethyl Sulfate; Methyl and Ethyl Acetoacetates; Glycol Diacetate; Glycol Diformate; Ethyl Silicate; "Flexol" Plasticizers; and "Tergitol" Penetrants.—Brand names are "Carbitol," "Cellosolve," "Flexol," and "Tergitol."*

Esters are important solvents and plasticizers for cellulose esters, gums, and resins. They are used in lacquers and in the manufacture of pyroxylin plastics, photographic films, artificial leather, safety glass, dyes, and medicinals. "Tergitol" penetrants

TRADE-MARKED PRODUCTS INCLUDE

TERGITOL PENETRANTS | FLEXOL PLASTICIZERS | CHLOREX SOLVENT

are wetting agents that speed aqueous processes, and increase the spreading power of metal cleaning compounds, insecticide sprays, and dust-laying solutions.

ETHERS AND OXIDES—*Ethyl, Isopropyl, Butyl, Hexyl, and Dichlorethyl Ethers; Diethyl "Cellosolve" and Diethyl "Carbitol"; Dimethoxytetraglycol; Ethylene and Propylene Oxides; Dioxane.—Brand names are "Carbitol," "Carboxide," "Cellosolve," and "Chlorex."*

Ethers are extractants for fats, oils, and alkaloids, and are utilized to recover organic acids from aqueous solutions, an important process in the manufacture of cellulose acetate rayon. Some are used in the manufacture of insecticides, guncotton, pyroxylin plastics, and collodion. The petroleum industry employs "Chlorex" solvent in the preparation of the new "solvent extracted" type of lubricating oils. "Carboxide" fumigant is particularly adapted for fumigating foodstuffs, grain, clothing, furs, tobacco, and dwellings.

GASOLINE

Gasoline is derived from natural gas and from oil cracking, and is sold in bulk to various oil companies.

GLYCOLS—*Ethylene, Diethylene, Triethylene, Tetraethylene, Propylene, and Dipropylene Glycols.—Brand name for a glycol-base "anti-leak" liquid for gas main use is "Carboseal."*

Glycols are liquids used in making hydraulic brake fluids, electrolytic condensers, synthetic resins, lacquer plasticizers, emulsifying agents, and low-freezing dynamites. Some find application as moistening and softening agents for tobacco, composition cork, glue, and paper products, and as fiber lubricants. "Carboseal" anti-leak is used in gas mains to prevent losses through dried-out joint packings.

HYDROCARBON GASES—*Butane, Ethane, Ethylene, Isobutane, Methane, Propane, and Propylene. · Brand name for propane for domestic use is "Pyrofax."*

These gases are used as fuels where high calorific value is required, as refrigerants in domestic and industrial installations,

TRADE-MARKED PRODUCTS INCLUDE

CARBOXIDE FUMIGANT | Pyrofax GAS | CARBOSEAL ANTI-LEAK FOR GAS MAINS

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and as basic materials for the synthesis of many chemical compounds. Ethylene is widely used for accelerating the coloring of matured fruits and vegetables, principally citrus fruits, tomatoes, and bananas.

"Pyrofax" gas brings the convenience of gas fuel to homes, institutions, restaurants, and industrial plants located beyond the city gas mains. The gas is delivered in steel cylinders through a chain of over 350 distributing stations and is used with standard gas ranges, water heaters, gas refrigerators, and other gas burning appliances. "Pyrofax" gas is also used with oxygen for cutting steel; for carburizing or casehardening; and in many industrial applications where a fuel of uniform composition is required.

KETONES—*Acetone; Diacetone Alcohol; Mesityl Oxide; Methyl Amyl, Methyl Isobutyl, and Diisobutyl Ketones; Isophorone.*

Ketones are solvents for cellulose esters, oils, "Vinylite" and other resins, and many organic compounds. They are used in the manufacture of lacquers, rayon, artificial leather, photographic films, pyroxylin plastics, smokeless powder, and as alcohol denaturants. Acetone is used in acetylene cylinders as a solvent for the gas.

PLASTICS, RESINS, AND WAXES—*Brand names are "Bakelite," "Carbowax," "Halowax," "Vinylite," "Vinylseal," and "Vinyon."*

"Bakelite" plastics include two general types of products: thermosetting phenol-formaldehyde and urea-formaldehyde materials, and thermoplastic cellulose acetate and polystyrene. These products can be classified generally as: materials for molding and extrusion; cast resinoids in many colors and of various textures; liquid resinous products for the impregnation of brake linings and electrical equipment; cements, adhesives, and bonds for lamp bulb bases, plywood, and abrasive wheels; resinoid varnishes for the production of laminated materials, such as wall

TRADE-MARKED PRODUCTS INCLUDE

BAKELITE PLASTICS | VINYON SYNTHETIC FIBER YARNS | Vinylite RESINS

paneling, silent automotive and industrial gears, table or desk tops, and instrument panels; synthetic resins for the production of all types of highest quality paint and varnish products, both for baking and air-drying finishes; heat-hardening lacquers and varnishes for coating chemical processing equipment, metal hardware, and other metallic surfaces; calendering materials for coating electrical insulation, metals, and fabrics.

"Vinylite" resins comprise another important group of synthetic resins and plastic materials. They are available in several forms: as powder; as granules for molding; and as sheets, film, permanently flexible sheeting, resin-coated paper, and extruded rods and tubes. Some are fabricated into colorful combs and toothbrush handles, or into records for electrical transcriptions, while others have become important insulating materials for various types of wires and cables. In another form they serve as the interlayer for high-test safety glass. When used as surface coatings, these resins are extremely resistant to the action of alcohols, acids, and alkalies. The flexible sheeting is finding wide application as shoe uppers, belts, and suspenders; in a thinner form it is used for shower curtains, raincoats, and other wearing apparel.

"Vinyon" synthetic fiber yarn, made by rayon manufacturers from "Vinylite" resin, is being used for industrial filter cloths, marine twine, and other applications where high tensile strength, elasticity, and chemical resistance are required.

The "Halowax" products are chlorinated hydrocarbons, synthetic resins, and various combinations of these products. They are used in industry as dielectrics, flameproofing agents, lubrication additives, and as plasticizers.

"Carbowax" compounds are non-volatile, water-soluble solids which resemble paraffin and petrolatum in appearance and texture, and are used as water-soluble textile lubricants; as paper and leather plasticizers; and as bases for water paint, shoe polish, sizing, and art crayons.

TRADE-MARKED PRODUCTS INCLUDE

VINYLSEAL ADHESIVES | HALOWAX SYNTHETIC WAXES | CARBOWAX COMPOUNDS

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PRODUCTS AND SERVICES

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PRINCIPAL PRODUCTS AND SERVICES – CURRENT

Specialties and Intermediates

Industrial Performance Chemicals

Union Carbide manufactures a broad range of ethylene oxide derivatives and formulated glycol products. These include CARBOWAX polyethylene glycols with a wide range of applications in pharmaceutical, personal care, household and industrial markets; ethanolamines for detergents, personal care products and in natural gas conditioning and refining; ethyleneamines for many industrial uses; TERGITOL and TRITON specialty and commodity surfactants for institutional and household cleaning products and for other applications; UCON fluids and lubricants; and alkyl alkanol amines. Formulated glycol products include UCAR and ULTRA deicing and anti-icing fluids for the aviation industry, UCARTHERM and NORKOOL heat transfer fluids, and gas treating products, including UCARSOL and SELEXOL solvents.

Manufacturing Sites – Taft, LA; Seadrift and Texas City, TX; Institute and South Charleston, WV; and Wilton, UK.

Specialty Polyolefins

Specialty Polyolefins manufactures and markets wordwide a variety of performance polyolefin products. Chief among these are polyolefin-based compounds for sophisticates insulation, semiconductives and jacketing systems for power distribution, telecommunications and flame-retardant wire and cable applications. Other specialty polyolefins products are used in adhesives, flexible tubing, and beer-can and soda-can six-pack carriers.

Manufacturing Sites – Bound Brook and Somerset, NJ; Seadrift, TX; Antwerp, Belgium; Cubatao, Brazil; and joint ventures in Gonfreville, France, and Kawasaki, Japan.

UNIPOL Systems

UNIPOL Systems licenses UNIPOL Process technology, the most cost-efficient and versatile method of manufacturing polyethylene, to producers of these products worldwide. It also develops new process technology for the manufacture of other olefins-based polymers, such as ethylene-propylene rubber, and sells catalysts to UNIPOL Process licensees world wide.

Manufacturing Sites – Norco, LA; Bound Brook, NJ; Houston and Seadrift, TX; and South Charleston, WV.

Solvents and Intermediates

Solvents and Intermediates supplies one of the industry's broadest product line of solvents and intermediates. Among its products are aldehydes, acids, alcohols, inccluding high-qualty synthetic and fermentation ethanol; esters; glycol ethers (CARBITOL and CELLOSOLVE solvents); ketones; and monomers (vinyl acetate and acrylics for polymers and waterborne coatings). Its principal customers are the paint and coatings industries, and many of its products are also widely used in cosmetics and personal care preparations, adhesives, household and institutional products, drugs and pharmaceuticals, fuel and lubricating oil additives, and agricultural products. The Company s UNICARB SYSTEM is a pollution-reducing, supercritical fluid technology for spray-applied coatings that can cut costs and reduce volatile organic compounds by 80 percent.

Manufacturing Sites – Taft, LA; Seadrift and Texas City, TX; Institute, WV; and Wilton, UK.

Specialty Polymers and Products & UCAR Emulsion Systems

Specialty Industrial Products produces acrolein derivatives, glutaraldehyde, vinyl methyl ether, ethlidene norbornene (ENB), specialty ketones, and biocides used to control microorganisms in applications such as sterilants, water treatment, papermaking, metalworking, oilfield operations, and industrial preservatives.
Performance Polymers include POLYOX water-soluble resins used in personal care products, pharmaceuticals, inks, and thermoplastics; and polyvinyl acetate resins used in chewing-gum resins, low-profile additives, Neulon polyester modifiers, fast-cure additives, and pigmentable systems.
Coating Materials products include CELLOSIZE hydroxyethyl cellulose (HEC); UCAR solution vinyl resins, TONE caprolactone-based materials, and cycloaliphatic epoxides, including CYRACURE ultraviolet-curing products, and FLEXOL plasticizers. Markets include paints, coatings, inks, substrates and other materials for magnetic tapes, food and beverage packaging, plastics, and orthopedic materials.

Manufacturing Sites – Taft and Greensburg, LA; Edison, NJ; Mamaroneck, NY; Texas City, TX; Institute and South Charleston; WV, Antwerp and Vilvoorde, Belgium; and Aratu, Brazil.

UCAR Emulsion Systems products, used in interior and exterior house paints, include UCAR latex products (acrylics and vinyl-acrylics that impart enhanced staining, weather, and scrub resistance to paints) and POLYPHOBE thickeners.

Manufacturing Sites – Torrance, CA; Tucker, GA; Alsip, IL; Somerset, NJ; Bayamon, PR; Garland, TX; Guayaquil, Ecuador; Jakarta, Indonesia; Seramabam, Malaysia; Guangdong, PRC; Batangs, Philipines; Ekala, Sri Lanka; Nonthaburi, Thailand; Jebal Ali Free Trade Zone, Dubai, United Arab Emirates.

Basic Chemicals and Polymers

Olefins

Union Carbide manufactures about three-quarters of its ethylene requirements and more than one-half of its propylene requirements. Ethylene and propylene are the key raw materials for Union Carbides olefin-chain businesses.

Manufacturing Sites – Taft, LA; Seadrift and Texas City, TX; a joint venture at Montreal,Quebec.

Ethylene Oxide and Glycol

Union Carbide is the world's leading producer of ethylene oxide and glycol. Ethylene oxide is a chemical intermediate primarily used in the manufacture of ethylene glycol, polyethylene glycol, glycol ethers, ethanaolamines, surfactants, and other performance chemicals and polymers. Ethylene glycol is used extensively in the production of polyester fiber, resin, and film; automotive antifreeze, and engine cooolants. Other ethylene oxide-based products include diethylene glycol, triethylene glycol, and tetraethylene glycol used as chemical intermediates and in dehydrating natural gas.

Manufacturing Sites – Taft, LA; Seadrift and Texas City, TX; Institute, WV; Prentiss, Alberta; Wilton, UK; a joint venture at Prentiss, Alberta.

UNIPOL Polymers

Union Carbide is a leading manufacturer of polyethylene, the world's most widely used plastic. UNIPOL Polymers produces and markets low-density, linear low-density, medium density, and high-density polyethylenes used in high-volume applications such as housewares, milk and water bottles, grocery sacks, trash bags, packaging, and water and gas pipes. FLEXOMER very-low density resins are used as a polymer modifier in other polyolfins and to produce flexible hose and tubing, frozen-food bags, and stretch wrap.

Manufacturing Sites – Taft, LA (Star Plant); Bound Brook, NJ; Seadrift, TX; Boucherville, Quebec.

Partnerships and Corporate Joint Ventures

UOP This partnership with Allied Signal, Inc. is a leading worldwide supplier of process technology, catalysts, molecular sieves, and adsorbents to the petrochemical and gas-producing industries. UOP has facilities in Mobile, AL; Anaheim and El Dorado Hills, Ca; Des Plaines and McCook, IL; Shreveport, LA; Tonawanda, NY; Shanghai, PRC; Reggio di Calabria, Italy; and Brimsdown, UK.

Nippon Univar Company, Ltd This is a Japan-based producer of commodity and specialty polyethylene resins and specialty silcones products. The joint venture with Tonen Corporation has a facility in Kawasaki, Japan.

Aspell Polymers SNC This is a producer of specialty polyethylenes. The partnership with Elf Atochem has a facility in Gonfreville, France.

World Ethanol Company This is a a U. S.-based partnership with Archer Daniels Midland that supplies ethanol worldwide.

Asian Acetyls Company, Ltd This is a South Korea-based producer of vinyl acetate monomers, used in the production of emulsion resins by customers in the coatings and adhesives industries, and is a joint venture with BP Chemicals and Samsung Fine Chemicals Company. It has a facility in Ulsan, Korea.

EQUATE Petrochemical Company, KSC This joint venture with Petrochemicals Industries Company and Boubyan Petrochemical Company, both of Kuwait, has a world-scale petrochemicals complex in Shuaiba, Kuwait, for the manufacture of polyethylene and ethylene glycol. (Completed in 1997.)

Petromont and Company Limited Partnership This Canada-based olefins and polyethylene resins producer is jointly owned with Ethylec, a subsidiary of SGF in Quebec. The partnership has facilities in Montreal and Varennes, Quebec.

Alberta & Orient Glycol Company, Ltd This is a joint venture with Mitsui 4 Company, Ltd, Japan, and Far Eastern Textile Ltd, Taiwan. It is a Canada-based producer of ethylene glycol with a facility in Prentiss, Alberta.