A HISTORY OF UNION CARBIDE CORPORATION

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 feed-stocks 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 -63-

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 uranium 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.

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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.

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

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

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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.

A HISTORY OF UNION CARBIDE CORPORATION

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.

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270 Park Avenue, New York, NY



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.



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Figure XXI Seadrift Plant in 1962



Figure XXII Torrance Plant in 1962



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 millionand-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. 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 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

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.