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 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 Britain, 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 atmosphere 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

Figure XI
Clendenin Gasoline Plant in 1921

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 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

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

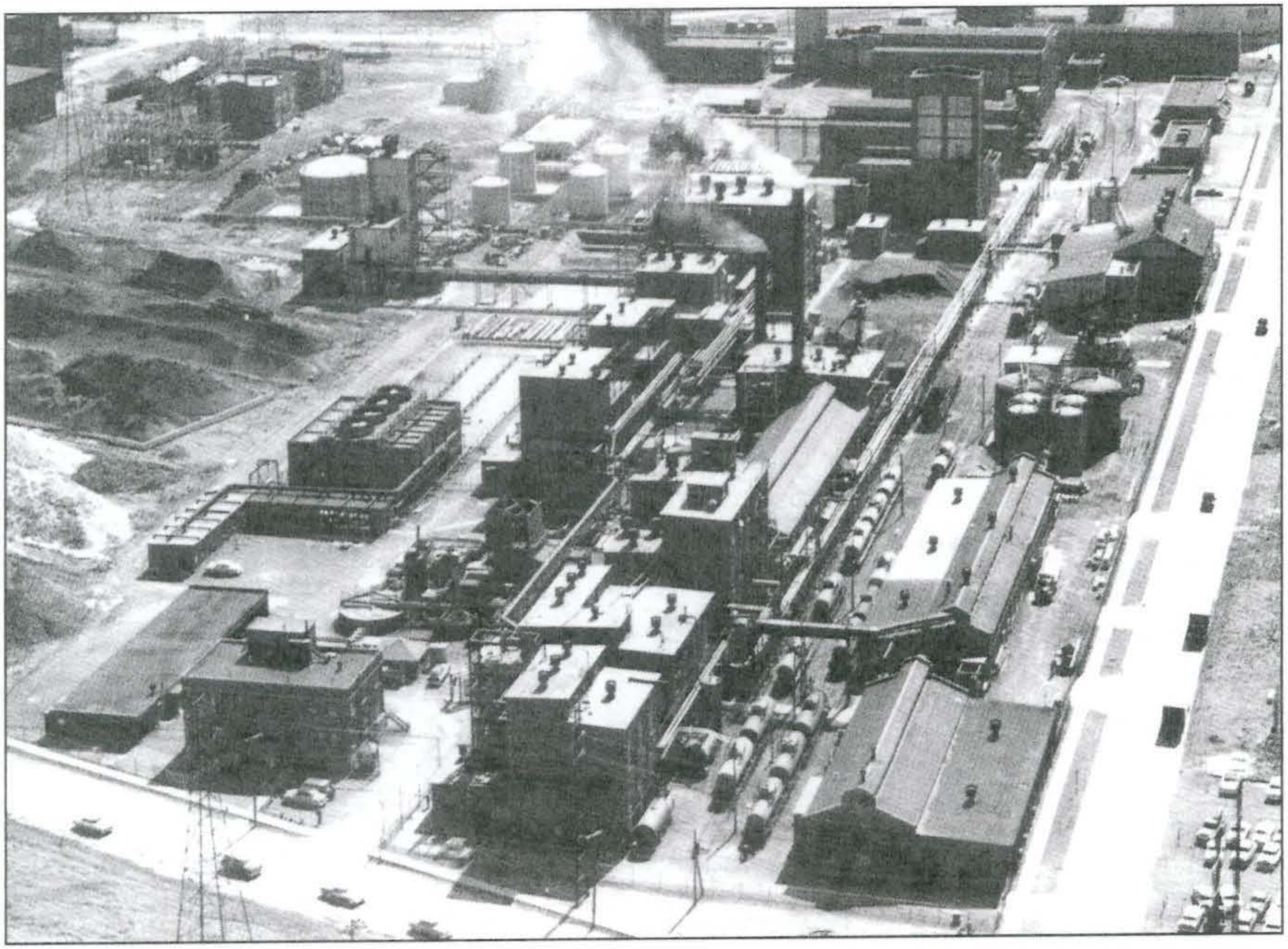

Figure XIII
Niagara Falls (Niacet) Plant in 1962

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 chemicals, 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

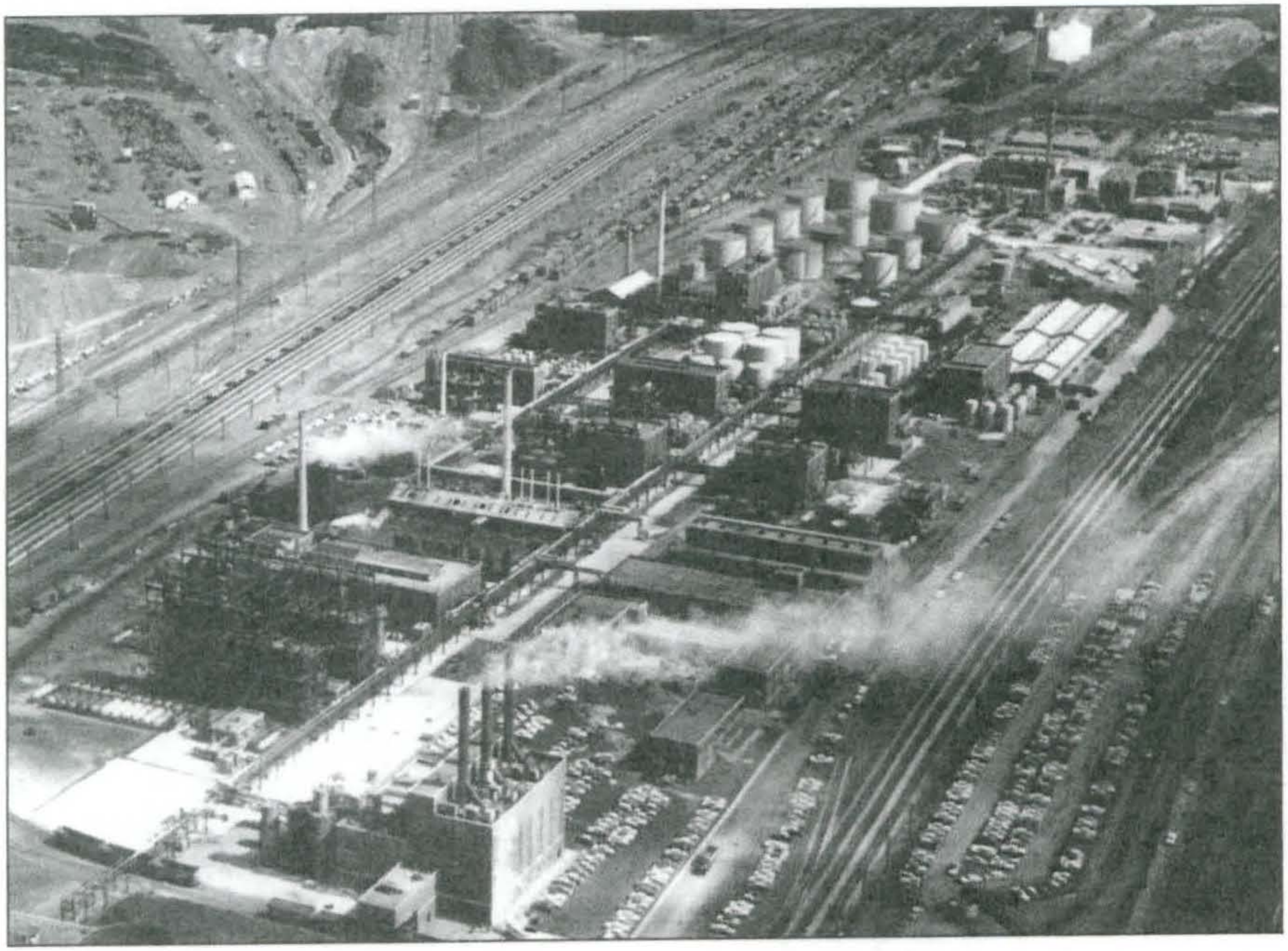

Figure XIV
Whiting Plant in 1962

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.

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.

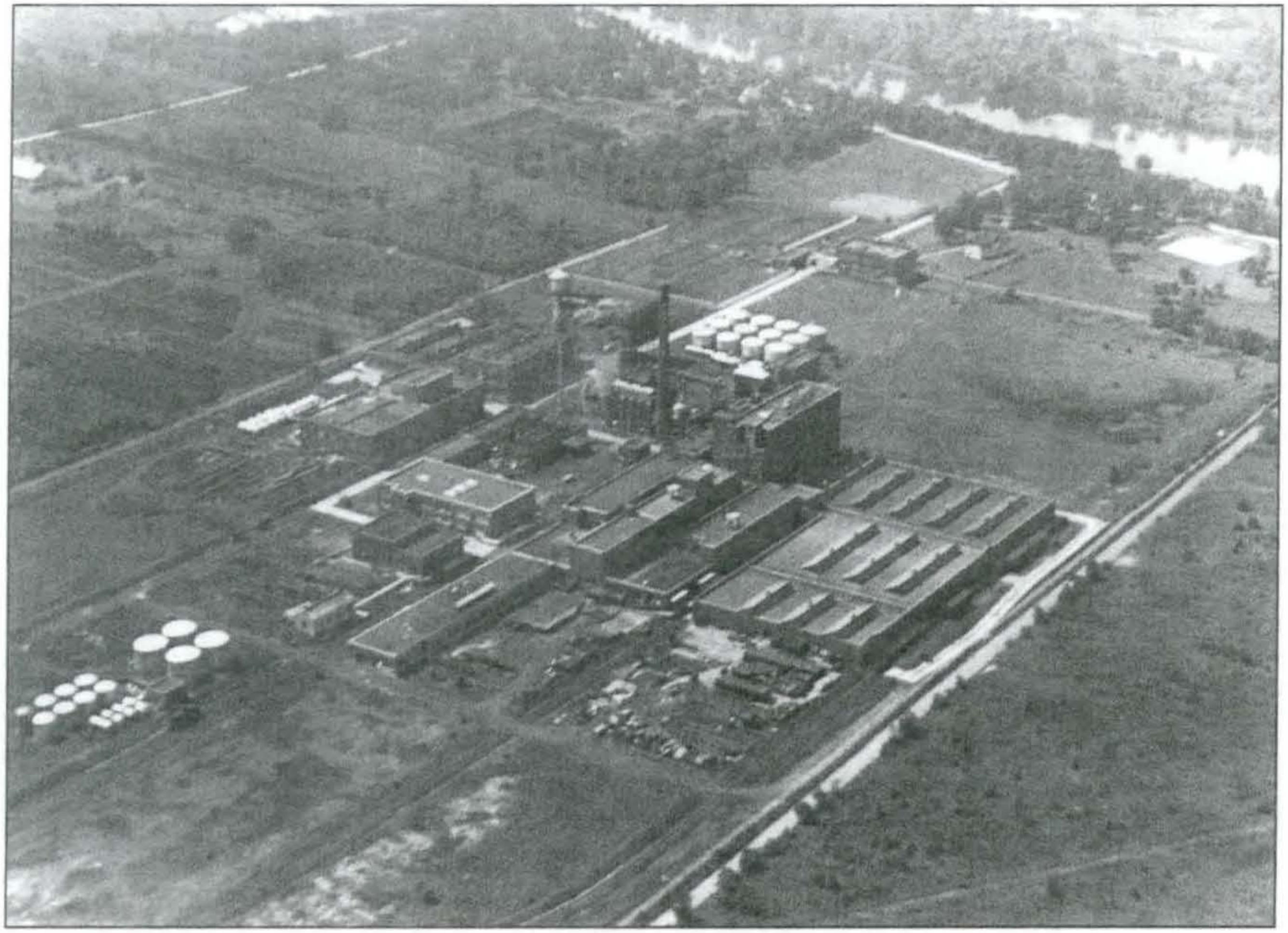

Figure XV
Bound Brook Plant in 1940

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 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.