Journal of Macromolecular Science, Part A
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597274

History of Reinforced Plastics

John V. Milewski[a]; Dominick V. Rosato[b]
[a] Los Alamos National Laboratory Los Alamos, New Mexico [b] University of Lowell Waban, Massachusetts

To cite this Article Milewski, John V. and Rosato, Dominick V.(1981) 'History of Reinforced Plastics', Journal of Macromolecular Science, Part A, 15: 7, 1303 — 1343
To link to this Article: DOI: 10.1080/00222338108056787
URL: http://dx.doi.org/10.1080/00222338108056787

J. MACROMOL.SCI.-CHEM., A15(7), pp. 1303-1343 (1981)

History of Reinforced Plastics

JOHN V. MILEWSKI

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

and

DOMINICK V. ROSATO

University of Lowell
Waban, Massachusetts 02168

ABSTRACT

This history of reinforced plastics is told by combining the individual histories of each reinforcement and the way in which they added to and changed the direction and rate of growth of the industry. The early history is based on all resins, fillers, and fibers found in nature. Then came the Baekeland revolution with the first synthetic resin which lasted about 25 years, at which time synthetic fiber glass and polyester resin dramatically changed the industry. Now, for the 1980s, the high modulus fibers developed 10 to 20 years ago are reshaping the industry.

We will start this history of reinforced plastics by quoting the opening paragraph from J. Harry DuBois's book The History of Plastics.

Two generations have seen the plastics industry grow from a hand made comb and novelty business into an industrial giant that

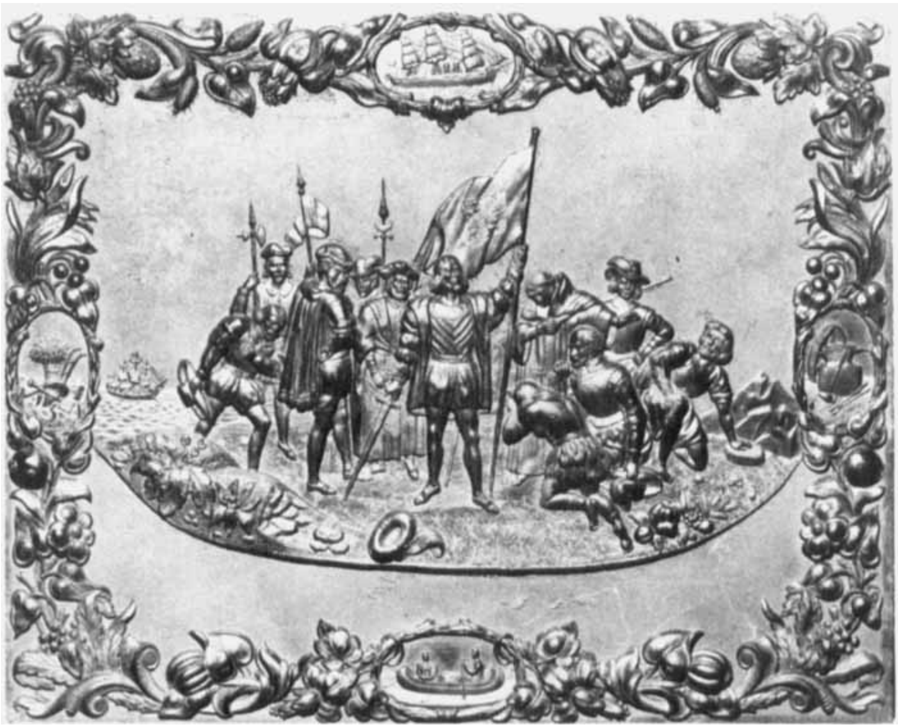

FIG. 1. Compression-molded photo case made of filled shellac plastic, 1852. (Figures 1-17 and 21 are courtesy J. H. DuBois.)

> is destined to dominate all of the basic materials. In the next decade the volume of plastics is expected to equal that of all metals and by the year 2000 the volume of plastics will exceed that of all basic materials.

To this quotation we will add our thoughts and predictions about reinforced plastics. We believe that there are very few applications of plastics which cannot be served equally and in many cases more economically by the same or similar plastic with a reinforcing filler or fiber or both.

As soon as the balance of the plastic industry perceives the economic advantages of using lower priced filler to lessen resin cost, then there will be very few plastic products that will not be made of reinforced plastics.

So this means that the extensive growth predicted by DuBois for the plastic industry will be the future of the reinforced plastic industry.

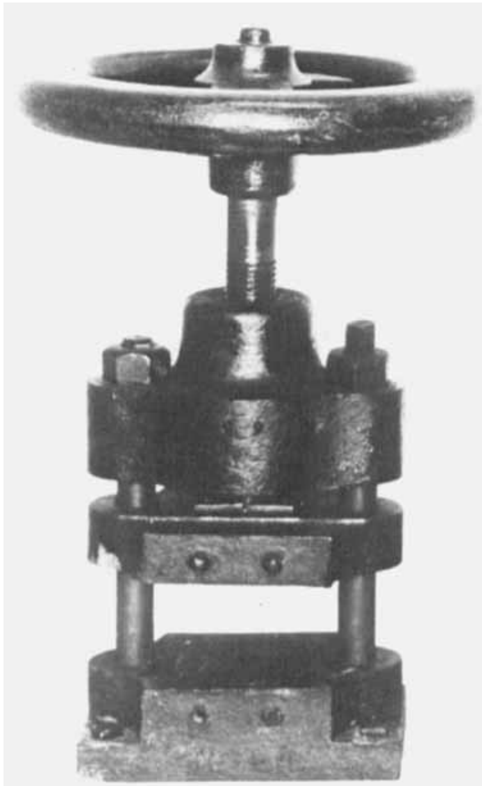

FIG. 2. A typical press used for early molding, 1860.

EARLY HISTORY: ALL NATURAL RESINS, FILLERS, AND FIBERS

The first resins and reinforcements were those refined from natural products. The first known plastic molder was Samuel Peck who began working with shellac plastic in 1852. Figure 1 is a compression molded photo case made of shellac and wood flour. Shellac was the pioneer resin for many early reinforced plastic applications that were converted to phenolics in later years.

Some of the other filler and reinforcements used in early plastics are given in the formulation that follows.

Compounds for Picture Frames

Straw pulp mixed with one-half ounce of gum shellac, a quantity of alcohol to cut the gum, one-half pint of glycerine, and a quantity of ammoniacal solution of copper to make the pulp moist.

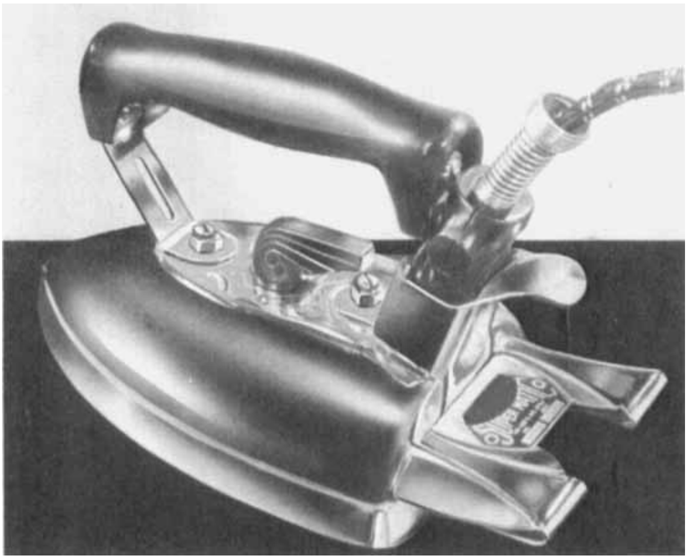

FIG. 3. An early cold molded part—an iron handle.

A typical press used for early molding ca. 1860 is shown in Fig. 2.

Around the turn of the century cold-molded plastics were developed in Europe by Emil Hemming, Sr. Around 1908 he came to America and pioneered cold-molded plastics in the field of electrical insulation. Some of his formulations were based on bituminous-asphaltic like resin binders and various filler reinforcements such as asbestos and diatomoceous earth. Figure 3 shows an early cold-molded part iron handle.

BAEKELAND'S BREAKTHROUGH—THE FIRST SYNTHETIC RESIN

DuBois lists 13 other scientists who tried and failed to make a usable resin from the reaction of phenol and formaldehyde. Baekeland (Fig. 4) dedicated himself to solving the phenolic resin enigma and after several years and endless experiments the real birth of the reinforced plastic industry took place in his home laboratory in Yonkers, New York (Figs. 5 and 6). He found a method of controlling the reaction; he could stop it at will while the resin was still in the fusibly soluble stage, which he named the A stage. He learned that with the resin in this stage he could dissolve it in solvents, mix with

FIG. 4. Dr. Baekeland.

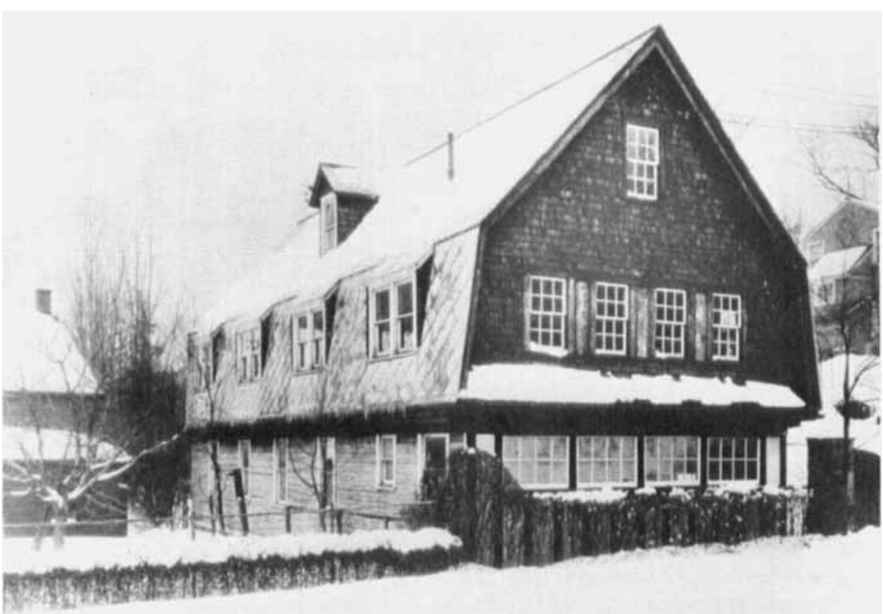

FIG. 5. Dr. Baekeland's home in Yonkers, New York.

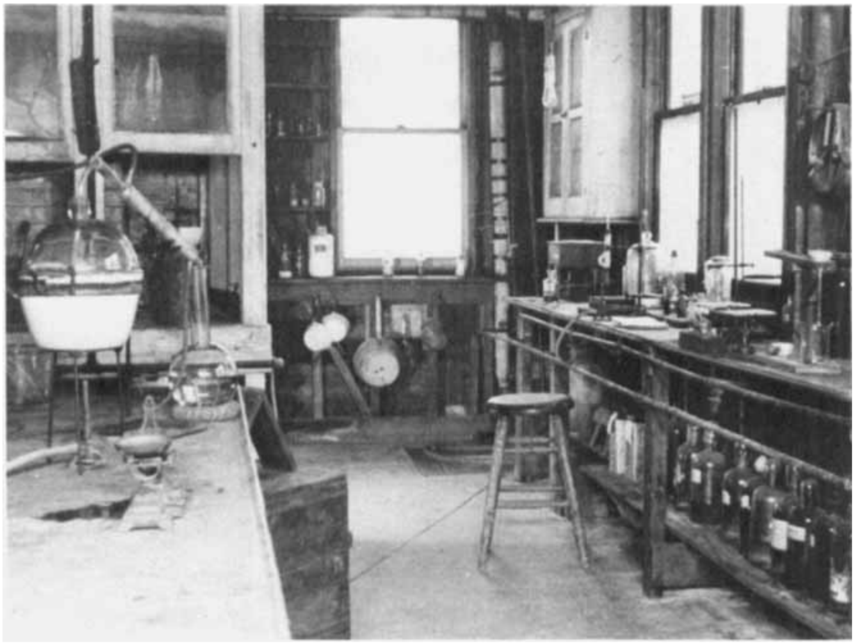

FIG. 6. Dr. Baekeland's laboratory in his Yonkers home.

fillers and reinforcements, and then proceed to the B stage which, although practically infusible and in soluble, was still thermosoftening to final shape in the mold where it took on the full cure to the fully inert C stage. This discovery is shown written in his own hand notebook dated June 20, 1907 (Fig. 7).

The first molded Bakelite parts (Fig. 8) were reinforced plastic, some molded with asbestos and some molded with wood flour as filler reinforcements. These were made in 1907 in Booton, New Jersey, by Richard W. Seabury of Loando Hard Rubber Co.

In 1909, after establishing patent coverage, Baekeland gave his first paper, "The Synthesis, Constitution and Uses of Bakelite," on his work at the New York Section of the American Chemical Society. This announcement, coming as it did from a man who already distinguished himself in the field of science and industry, attracted very wide attention and interest in financial supporters as well as prospective competitors, and as a result gave a big boast to the thermosetting molding business. By the middle of 1910 it was obvious that Bakelite had outgrown its production facilities which, by the way, consisted of a small cast iron jacketed still as shown in Fig. 9.

The electrical industry was expanding rapidly and so was the

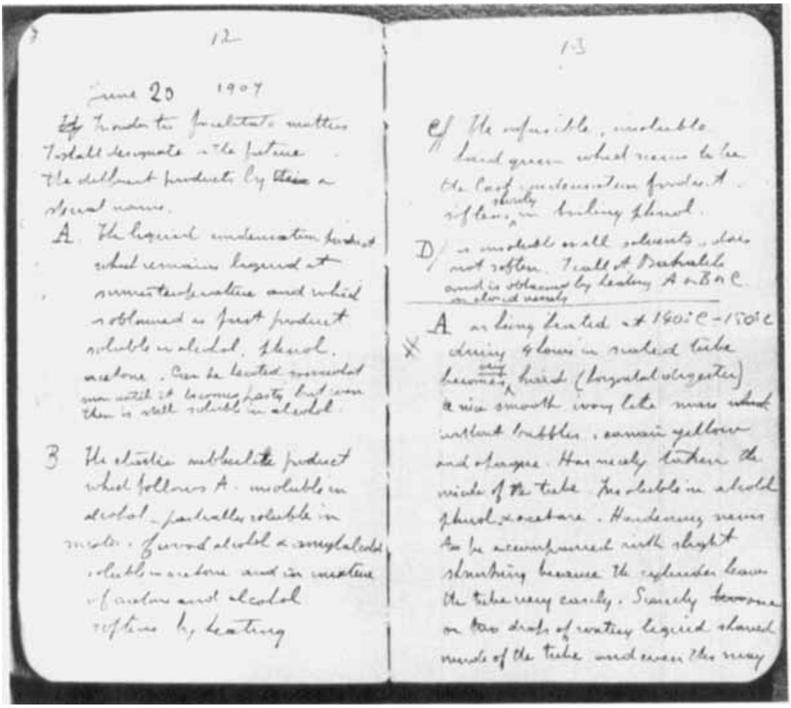

FIG. 7. Dr. Baekeland's notebook, dated June 20, 1907, describing his "A," "B," and "C" stage discovery on curing phenolic resins.

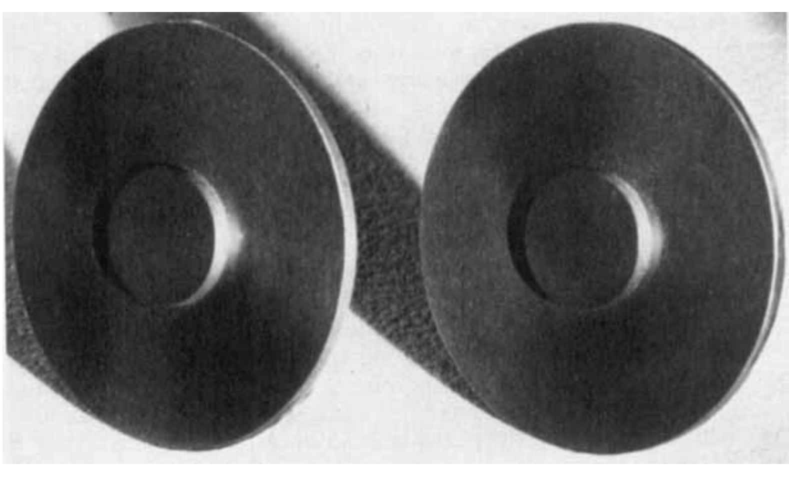

FIG. 8. The first molded Bakelite parts reinforced with asbestos.

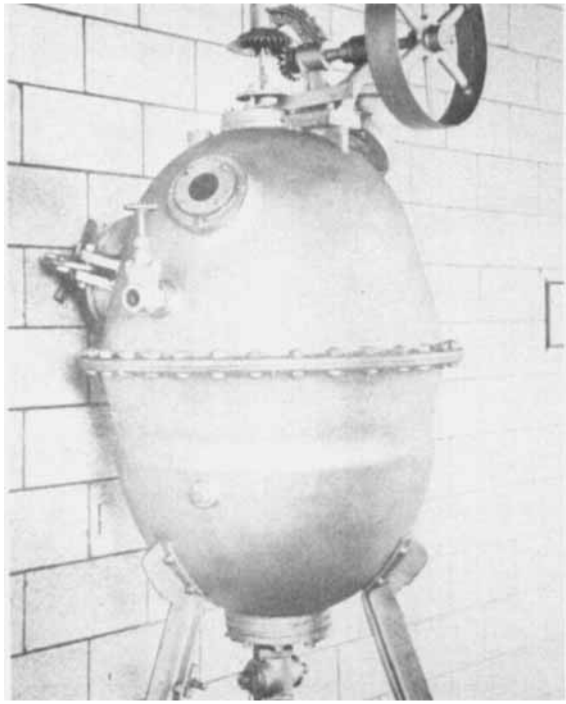

FIG. 9. The 1910 production facilities for Bakelite resin, a small cast iron jacketed still.

infant automotive industry, and both urgently needed a new insulation material, better electrically and more heat stable, stronger, and more amenable to mass production methods. The laboratory production methods was outgrown, so in 1911 General Bakelite Co. started operations in a greatly expanded facility in Perth Amboy, New Jersey, as shown in Fig. 10. The use of Baekeland's reinforced phenolic resin systems grew rapidly and in a few years many companies were using Bakelite plastic products. Some of the early companies were Booton Rubber Co., Westinghouse Electric Co., Renny Electric Co., Western Electric Co., Kellogg Switchboard Co., Albany Billiard Co., and Wagner Electric Co.

By 1916 reinforced plastics had come to the West Coast through the persistence of Earl Howard of the Gilfillan Brothers Plant in Los Angeles. They manufactured electrical, radio, and replacement parts for ignition systems on all makes of cars. The demand for these reinforced phenolic plastic parts was so great that within a year the company had grown from 14 to 44 presses in the 40 to 80 ton range. The market was there for reinforced phenolic plastic, then only known as Bakelite.

FIG. 10. General Bakelite Company's 1911 expanded facilities in Perth Amboy, New Jersey.

At this time Baekeland reported that the biggest limitation to growth was not the market but teaching people to use this new product correctly by avoiding the previous habits with shellac and rubber. At first he expected that anyone who understood molding would be able to make a success of Bakelite. He learned the hard way that it is difficult to teach an old dog new tricks. The knowledge of how to mold rubber, shellac, or celluloid in many cases was a block to progress. These older materials were thermoplastic; Bakelite was hardened by heat in the mold and needed high temperature and high pressure to produce the desired properties. He found that many older molders were habitually timid. They worked with low heat and got bad results. This same scenario has been repeated over and over again in the reinforced plastic industry each time a new material appeared that required significantly different processing conditions such as when new resin systems and/or new reinforcements were introduced.

By the early 1920s there were three companies producing phenolic resin materials: the Redmanal Chemical Products Co., the Condensite Corp., and the General Bakelite Co. In 1922 these three companies merged to become the Bakelite Corp. In 1939 the Bakelite Corp. became a unit of Union Carbide and Carbon Corp.

Another factor in the rapid growth during this period was the need in the telephone industry for receivers and mouthpieces which soon all became Bakelite. The wireless makers also found increasing applications for phenolic laminates. The need for thin section, high strength laminates spawned many laminate making companies of such familiar products as Micarter from Westinghouse, Formica from American Cyanamid, Phenolite from National Vulcarized Fibre Co., Textolite from General Electric, and Spaulding from Spaulding Fiber Co., in addition to Bakelite from General Bakelite Corp.

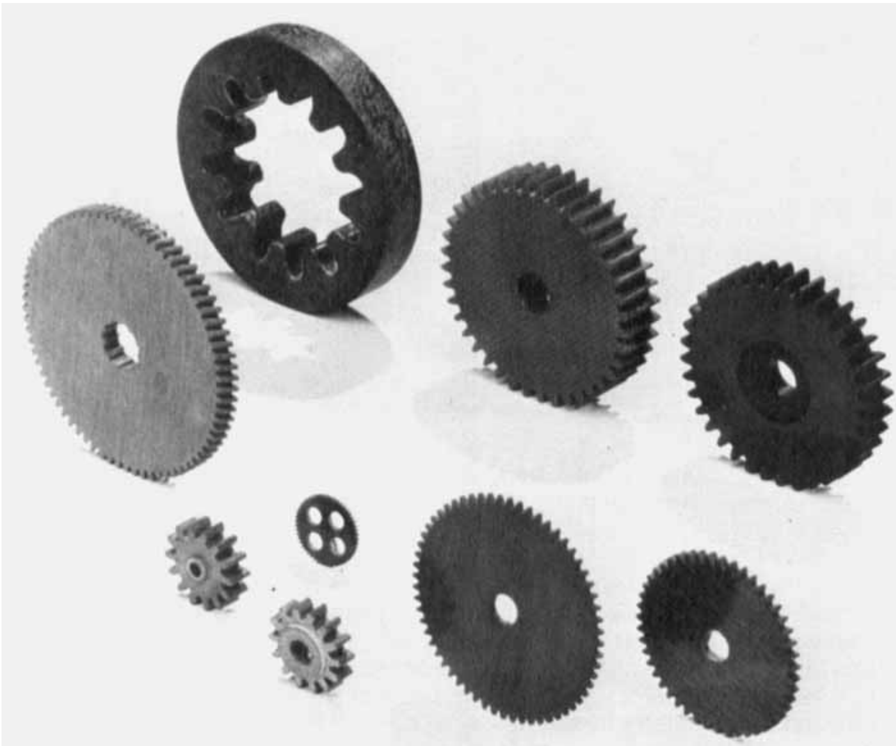

FIG. 11. Frank Conrad invented the use of laminated phenolic materials for gears, and a very large market developed therefrom.

VULCANIZED FIBER LAMINATER AND REINFORCED PLASTICS

Vulcanized fiber was invented by the Englishman Thomas Taylor in 1859 and was brought to America in 1871. The vulcanized Fibre Co. was licensed and formed in 1873.

Vulcanized fiber is a low cost cellulose fiber laminate made from a paper product that is vulcanized or bonded through the use of a zinc chloride bath and heat and pressure. It produces a very tough, easily fabricated, arc resistant insulation material. Unfortunately, it has a high moisture absorption that decreases electrical properties and causes warpage. Today it is still an important material but has lost many of its original electrical application to newer fiber-resin systems. The pioneer fiber makers were the Karlavert Co. in 1876, Delaware Hard Fibre Co. in 1892, American Hard Fibre Co. in 1894, and Diamond State Fibre Co. in 1895.

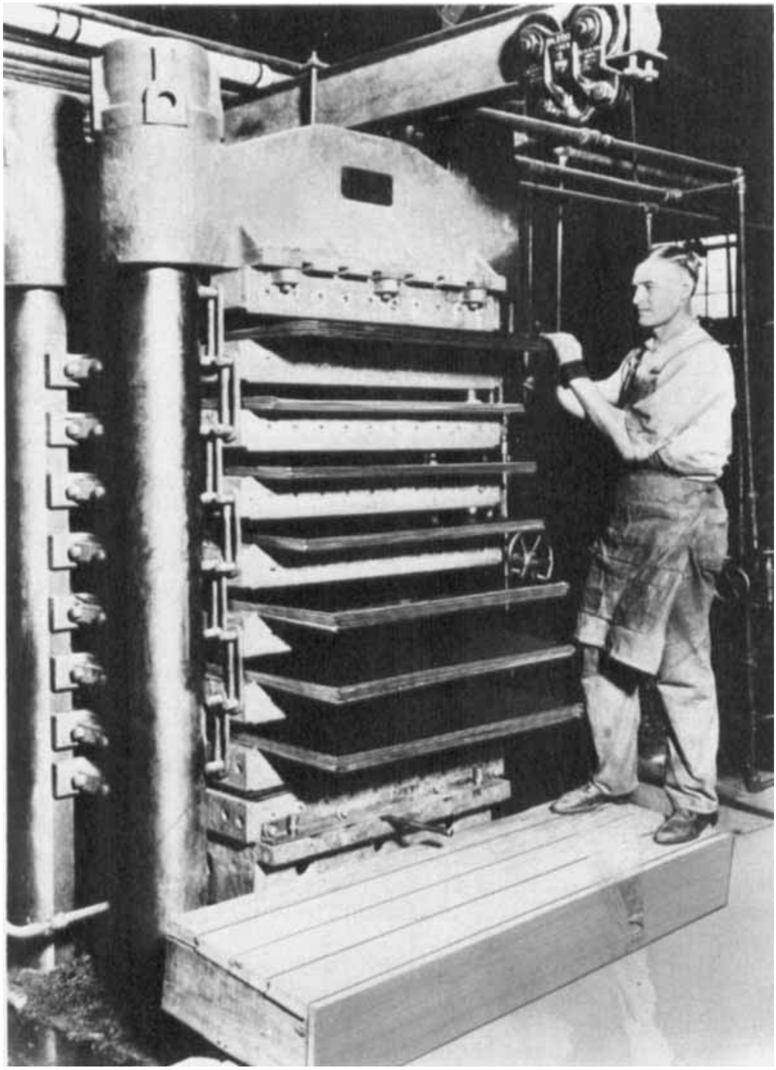

FIG. 12. Early multilayer presses for making phenolic laminates.

Karlavert Co. and American Hard Fibre Co. were absorbed by the American Vulcanized Fibre Co. In 1905 Continental Fibre Co. was formed and in 1929 it purchased Diamond State Fibre Co. and formed Continental Diamond Fibre Co. which was taken over by the Budd Co. in 1955. Iten Fibre Co. was formed in 1918 and National Vulcanized Fibre Co. was established in 1922. The Spaulding Fibre Co. entered

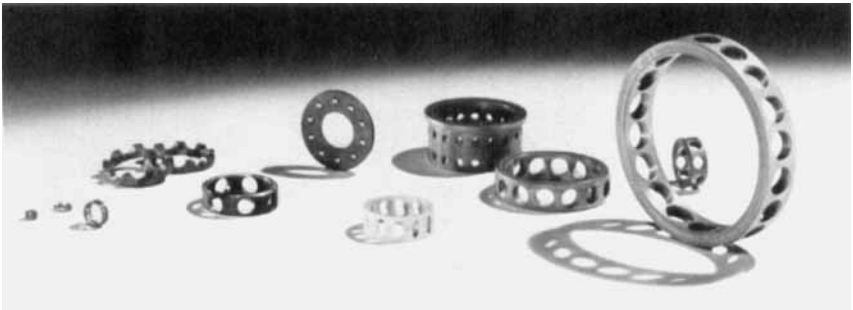

FIG. 13. Ball-bearing retainer rings fabricated from high-pressure laminates minimize wear, noise, lubrication, inertia, and malservice.

the vulcanized fiber field in 1906. Many of these companies moved directly into phenolic fiber laminates in the early 1920s.

The phenolic laminate sheets gained wide acceptance in many products. Typical are the gears shown in Fig. 11, the press used to make the sheets in Fig. 12 and the other parts shown in Figs. 13 and 14.

NEW RESINS AND FIBER GLASS ON THE SCENE

The late 1930s saw a new revolution in reinforced plastic with the advent of fiber glass and low-pressure curing polyester resins.

The development of glass filament started in the 1930s, ending in patents in 1936 by G. Slayler and J. H. Thomas. Owens Corning Fiberglass Co. was formed in 1935 to make and sell these fiberglass products. Glass wool for insulation and chemical filters were their first products.

Carleton Ellis did his own original work on polyester resins in 1933. The Ellis-Foster patent of 1937 covered production methods for making them.

The first glass fiber reinforced polyester products were made in 1938.

Polyester resins CR-38 and CR-39 were introduced commercially in 1940 by Pittsburgh Plate Glass Co. By 1942 American Cyanamid, DuPont, Libby Owens Ford Co., Plastion Co., and Marco Chemical were all producing polyester resins.

In 1942 the Air Force issued a contract to Marco Chemical Co. of Linden, New Jersey, where Irving Muskat continued the development of polyester resins. At this time the Air Force was looking for alternative material for magnesium, plywood, and aluminum, and heavily supported the development of low-pressure laminates. As

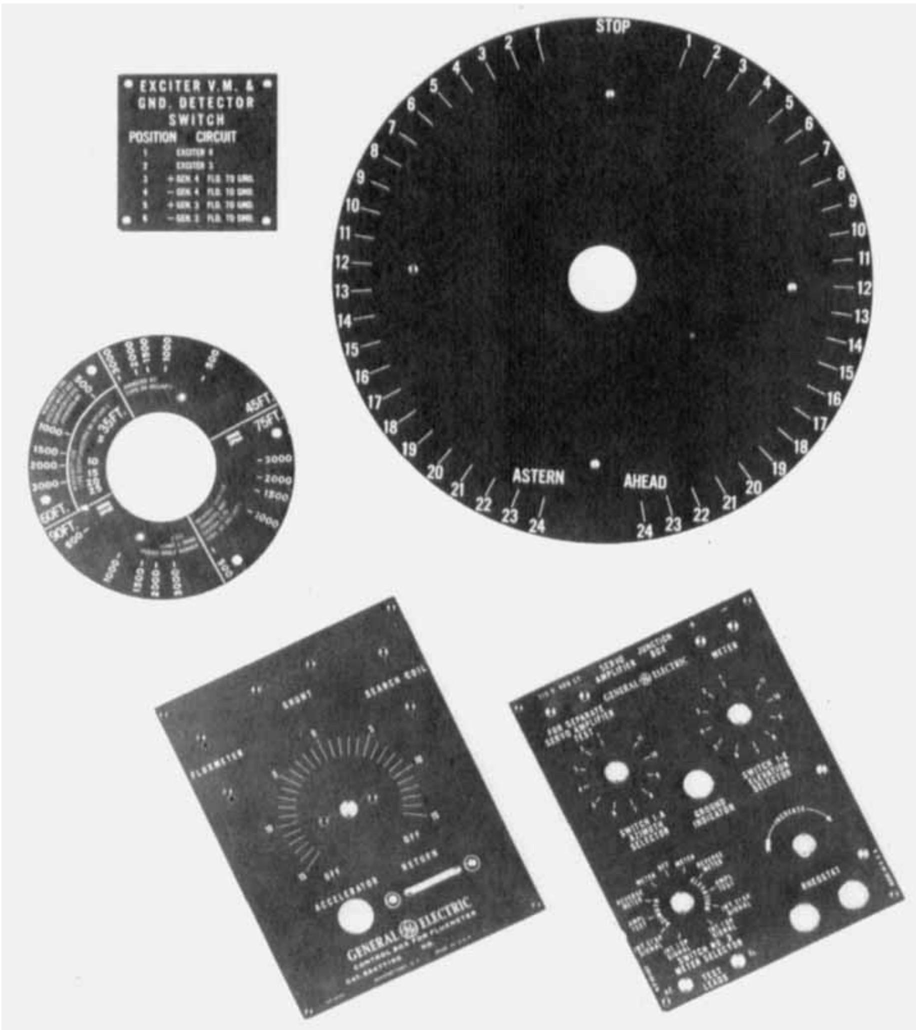

FIG. 14. Panels made of laminated phenolic used as radio dials.

a result of this, by the end of 1942 low-pressure RPs were being molded by Uniroyal, Goodyear, Formica, Boeing, Douglas, Gruman, Westinghouse, General Motors, General Electric, and Swedlow. Production of FRP became tremendous overnight.

The Navy secured its first RP boat in 1946. Laminated fiberglass sheet stocks of CR-38 and CR-39 resins were soon made available by P.P.G. Co. for aircraft, boats, and automobile parts.

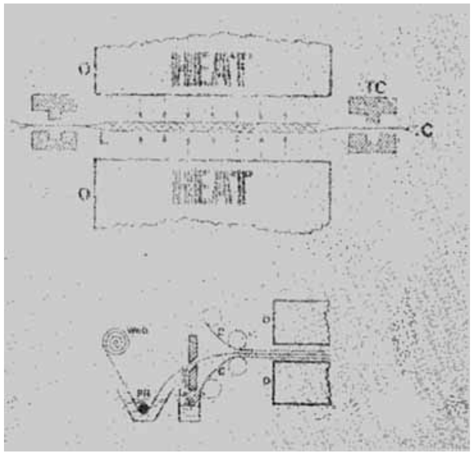

FIG. 15. In 1942 Continental Corp. set up a continuous low pressure, polyester laminate process.

In 1942 Continential Corp. set up a continuous low-pressure polyester lamination process as seen in Fig. 15. In 1943, WPDC approved structural sections with high strength polyester glass laminates for aircraft and missile components.

In 1944 the Society of the Plastic Industries organized the Low Pressure Industries Division.

In 1946 the introduction of epoxy resins gave added strength to reinforced plastics. The filament winding process was under development by R. E. Young and M. W. Kellogg for the production of rocket motor cases (Fig. 16) and filament wound pipe.

Also, 1946 saw the first molding of production fiber-glass parts in low-cost matched metal dies by Larry Wittman, then working at Republic Aviation.

A rigid fiber-glass shelter was built in 1946 to protect observers who were tracking balloon-borne weather transmitters. These shelters, now called Radomes, have been installed all over the world (Fig. 17).

In 1947 Dr. Irving Muskat developed the first thixotropic resin at Marco Chemical Co.

In 1948 the Fiber Reinforced Thermoplastic Industry (FRTD) began to expand in a big way with the injection molding of a toilet seat for the Church Seat Co. They claimed it to be the best seat in the house.

Also in this year, the SPI changed the name of the Low Pressure Industries Division to the Reinforced Plastics Division.

Another major significant activity in 1948 was the introduction of the first polyester-glass premix molding compounds by Roger White and Larry Seidel of Glastic Corp.

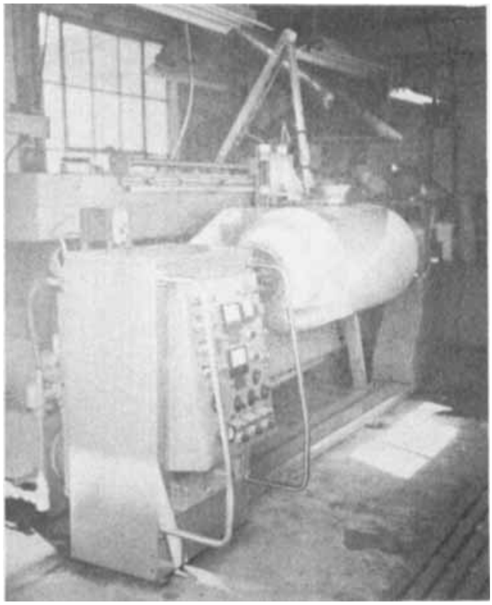

FIG. 16. Filament winding process for making high strength rocket motor cases.

In 1949 Molded Resin Fiber Co. received the first mass production contract for the use of matched metal molds and hydraulic presses producing 1000 parts per day.

By 1950 the FRP Boat Industry expanded to the point that 22 FRP boats were exhibited at the boat show (Fig. 18).

Also in 1950, FRP boats had also rapidly moved into helicopter blades and dropable fuel tanks for aircraft used in Korea.

In 1951 Kaiser-Darrin introduced the first production sport car with an all FRP body. Another major development in 1951 was the first workable chopper for production of chopped strand which opened the door to sprayup technology (Fig. 19).

During this year the production of fiber glass expanded with O.C.F. granting licenses to Ferro, P.P.G., L.O.F., and Gustin Bacon to produce fiber glass.

The first chrome complex patent was issued based on DuPont's Voland finishes and the allylsilane glass size was patented by Robert Steinman. This was the predecessor of the silane coupling agents. In 1952 American Cyanamid introduced their general purpose polyester resin which significantly improved processability in FRPs.

In 1953 the Mobile Plastics Division of Carlyle Corp. introduced the first preimpregnated roving. From 1953 to 1955 General Motors,

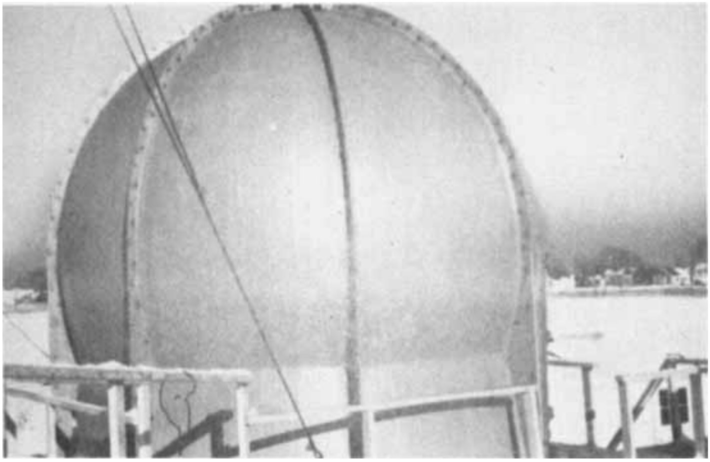

FIG. 17. This first radome was started in 1946 for tracking balloon-borne transmitters. It was made of polyester and fiber glass in white-metal molds and installed at Sault Sainte Marie, Michigan. (Courtesy N. W. Rakenlow.)

FIG. 18. Typical of many makes and models of fiber glass boats.

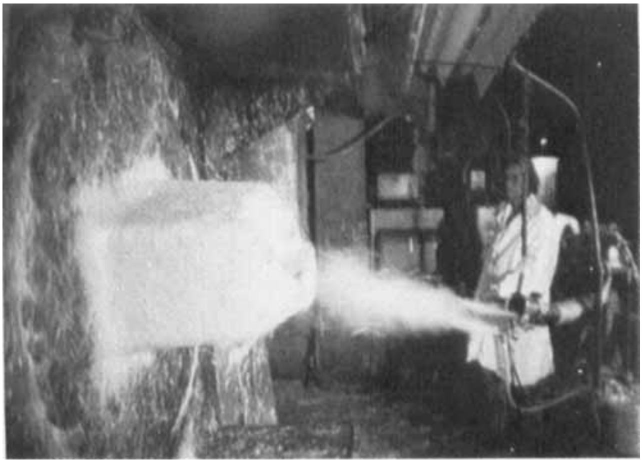

FIG. 19. Spray-up technology where chopped fibers and resin are sprayed together on a mold form.

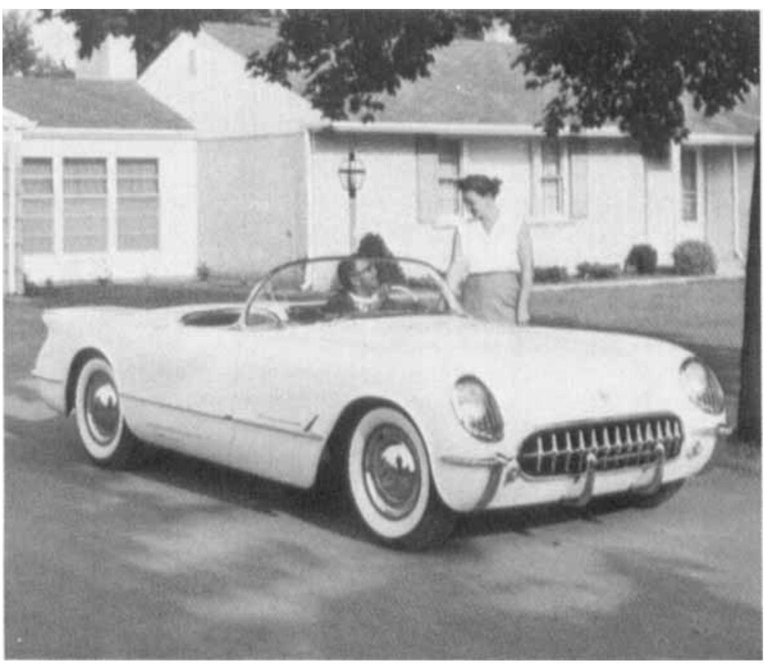

FIG. 20. The 1953 Chevrolet Corvette was the first production car with a fiber glass body, molded by Molded Fiberglass Co.

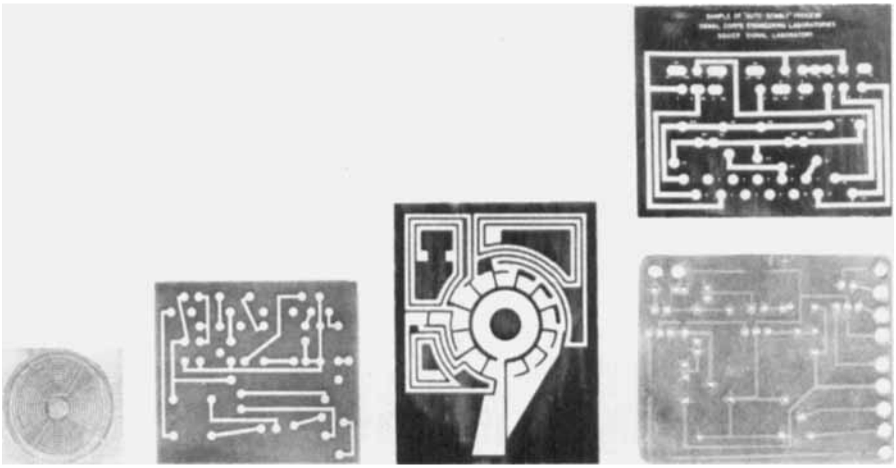

FIG. 21. Fiber glass epoxy laminates are widely used for printed circuit boards.

working with Molded Fiberglass Products Co., launched an exploratory program with its Chevrolet Corvette all FRP body. In the first production year, 300 were produced using vacuum bag, aerospace technology (Fig. 20). The success of the Corvette pointed up the advantages of using FRP in the fabrication of large complex shapes in relatively low volume. This giant step matured into 140 million lb of FRP in automobile components in 1979.

In 1955, early ablation studies for phenolic fiber glass-asbestos components showed outstanding characteristics on Viking rocket flight tests.

The Taylor Craft Model 20 airplane uses FRP in wings, engines cowlings, doors, seats, fuel tanks, instrument panels, and fuselage skins from nose to fin trailing edges.

In 1956 fiber glass epoxy laminates are widely adopted for printed circuit boards, and its future use in the fast-growing computer business is assured (Fig. 21).

In 1957, FRP use was introduced to transit bus and subway seats (Fig. 22).

Fiber glass, which became available in the late 1930s, is now beginning to realize its full potential and expanding rapidly in many areas.

NEW FIBERS AND NEW TECHNOLOGY

In the late 1950s and early 1960s a new revolution began in reinforcing plastics with the development of a number of new higher

FIG. 22. Transit bus and subway seats made of FRP.

modulus reinforcing fibers such as carbon/graphite, boron, and whiskers, which now in the early 1980s are projected to expand into a wide variety of commercial applications competing with fiber glass.

In 1958 the first carbon fibers were made of rayon (Fig. 23). At the same time, Willard Sutton at the General Electric Co. was making sapphire whiskers for use in experimental metal and plastic composites. In 1959 Texaco reported on the development of boron, a high-strength, high-modulus (50 million psi) fiber. In 1963, Milewski and Shyne formed Thermokinetic Fibers and then made sapphire and beta silicon carbide whiskers available to the research community for the first time (Fig. 24).

Also in 1963 General Schreiver initiated project Forcast which was a survey on the direction for new high strength composites. The survey favored the development of boron fibers which he promptly backed up with millions of dollars of Air Force R&D monies. He stated that boron fibers were the greatest breakthrough in fiber composite in over 4000 years, since the Israelies began to put straw into mud bricks.

An important commercial event that occurred in 1963 was the first injection-molded thermoplastic elastomeric parts for an automobile production application—the instrument panel for the Cadillac.

In 1964 graphite fiber became available in research quantities. Also, in England, the British designers Gibbs and Cox started a feasibility study on a 300-ft mine sweeper of FRP which was to become a reality a few years later.

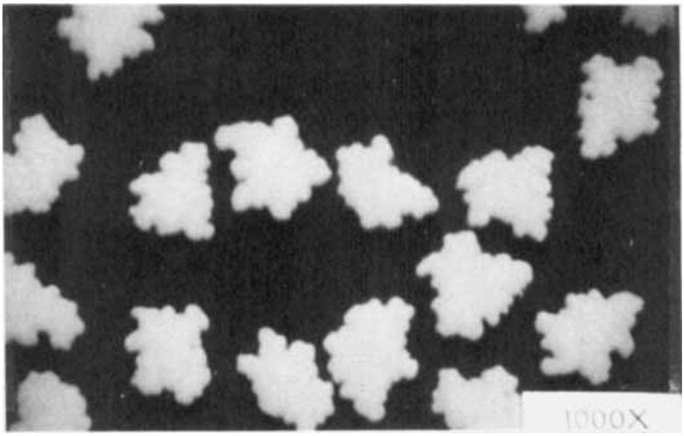

FIG. 23. Cross section of rayon-based graphite fibers.

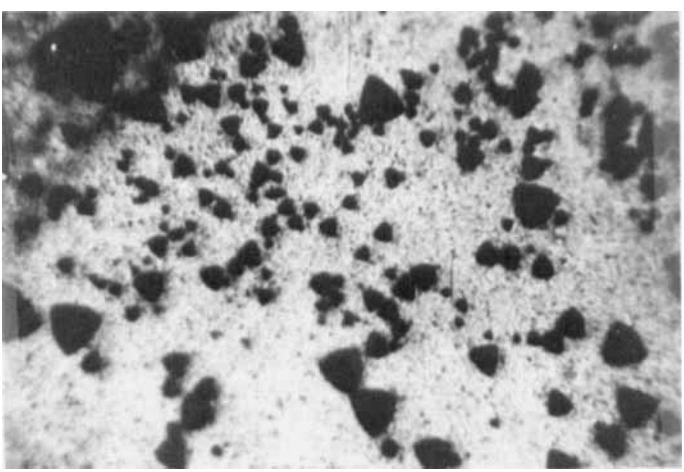

FIG. 24. Cross section of beta silicon carbide whiskers. 1000×.

FIG. 25. The Sears Gamefisher 12-ft fishing boats.

In 1965 the United States walk in space had FRP helmets, a filament wound attitude control gun, and a FRP survival kit.

In 1967, Windecker Research of Midland, Texas, flight tested a relatively all FRP single wing airplane made of fiber glass and epoxy resin.

The SPI changed the name of its Reinforced Plastic Division to the Reinforced Plastic/Composite Division in recognition of the broader and expanding range of composite materials.

Two new fibers became available in 1967: S-2 fiber glass, a commercial grade of S glass, and DuPont's potassium titanate fiber called Fybex. Fybex claimed to be the poor mans whiskers (which were selling at 40 to 50¢ a pound. Fybex turned out to be only a microfiber without the strength and elongation of a true whisker, and after a few years it lost market acceptance and was withdrawn.

Another important event in 1967 occurred when Bob Seagren broke the world pole vault record using a fiber glass composite pole.

Also, 1968 saw the first SMC automotive applications accepted. The SST was designed to include over 6000 lb of FRP and 6000 lb of non-reinforced plastic parts.

In 1969 a leading brassiere manufacturer replaces metal underwire with FRP. Sears introduced a 12-ft game fisher car top boat (Fig. 25), made by matched metal dies. Pontiac introduced SMC in their front end fender extender and lamp housing for the first high volume automotive application for SMC (Fig. 26).

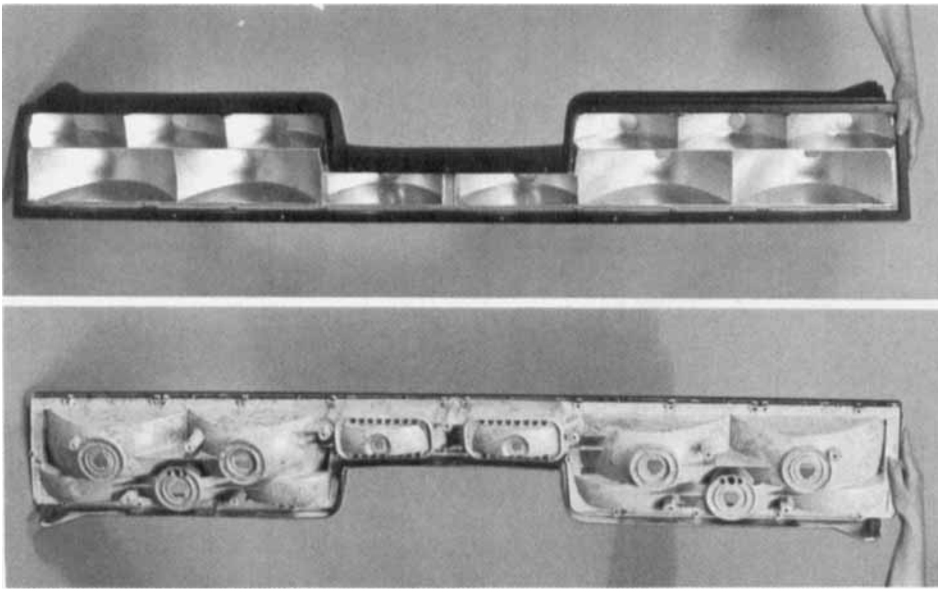

FIG. 26. SMC used in front end fender extender and lamp housing for the first high volume automotive applications.

FRP went to the moon on the Apollo Spacecraft with Neil Armstrong.

By 1970 there are over 10,000 FRP underground storage tanks in use, and other large size and large volume applications expanded [concrete forms (Fig. 27) and silos for grain storage].

In the early 1970s DuPont introduced Kevlar, an aramid fiber which fills the gap between high-cost, high-modulus carbon/graphite and low-cost, low-modulus fiber glass with an intermediate-cost, intermediate-modulus polymer fiber. This fiber is expanded rapidly in applications in the late 1970s and is destined for very rapid expansion in the early 1980s. It is the highest strength to weight fiber on the market and is extremely tough and durable during handling.

In 1972, the sales of FRP exceeded 1 billion pounds.

In 1973, Milewski introduced the concept of micropacking that gains from the use of both filler and fiber in combination which improves reinforcement efficiency and lessens resin demand.

By 1978 the total shipments of FRP composites exceeded 2 billion pounds. It took 26 years for the first billion and only 6 more years to reach the second billion pounds. This is a growth rate for that period of about 16% per year.

After the resin shortage and resulting higher resin costs of the mid-1970s, the RP industries looked for and began to accept a wide variety of additives such as filler and short fibers to extend the resin.

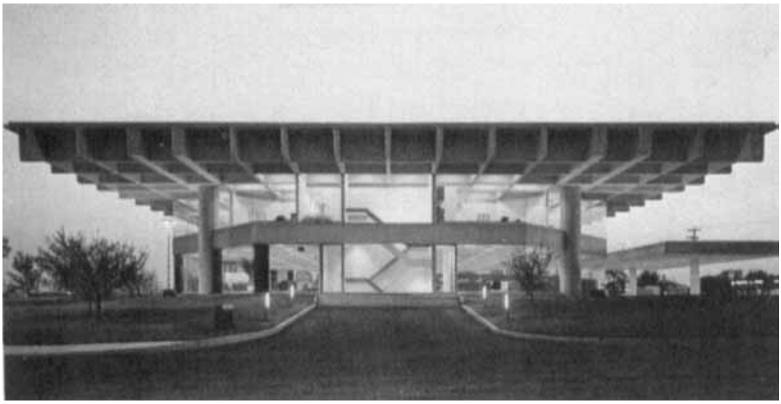

FIG. 27. FRP is used in concrete forms to make extensive concrete structures such as these.

FIG. 28. Short fibers such as PMF process mineral fibers are being used extensively to both reinforce and replace resin.

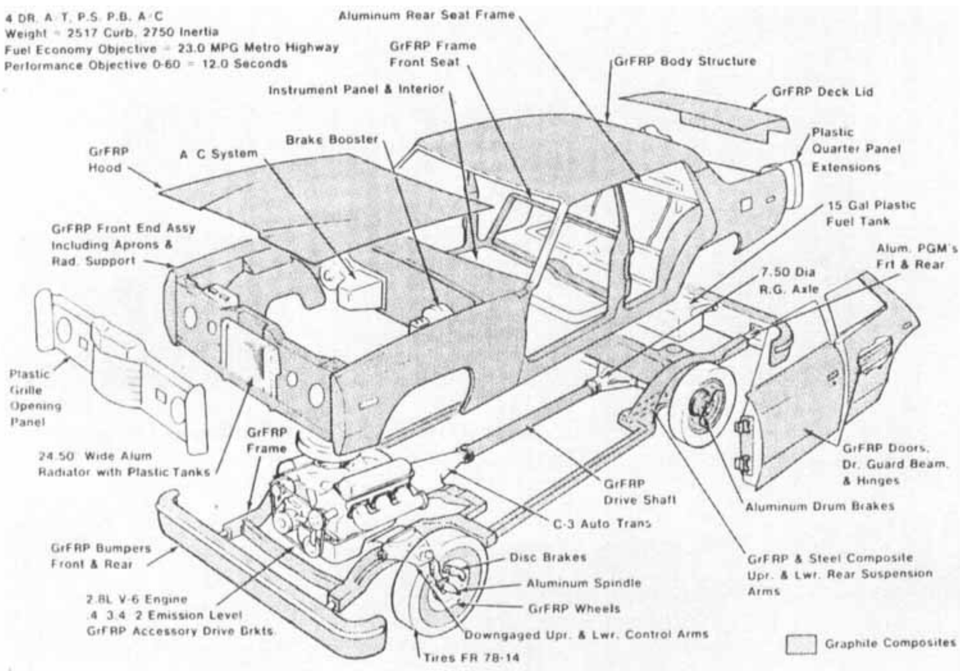

FIG. 29. Ford's lightweight vehicle program shows many structural and load bearing parts made of reinforced plastics.

New low-priced microfibers such as Franklin fiber and PMF were introduced to help fill these needs. There was also increased use of Wollastonite, a low-priced mineral fiber (Fig. 28). The Handbook of Fillers and Reinforcements for Plastics by Katz and Milewski indicated an increased emphases in this area.

1979 saw "S" glass being designed into almost every new aircraft of the Boeing 700 series. New forms of fiber reinforced materials were being added to aircraft as they become available (Kevlar skins, Nomex honey comb, "S" glass pre-pregs, etc.). FRP windmill blades of 150-ft were designed for energy projects.

1979 showed a wide variety of new, low-cost metal and metal-coated fibers introduced for the many new electromagnetic and electrostatic shielding applications that were previously being satisfied by the more expensive carbon/graphite fibers.

1980 will see the extensive use of hybrid fiber combinations such as glass-graphite, glass-Kevlar, and Kevlar-graphite as well as increased use of short fibers and fiber-sphere packing combinations.

The automotive industries is committed to lighter weight cars and that means reinforced plastics taking over more of the traditional

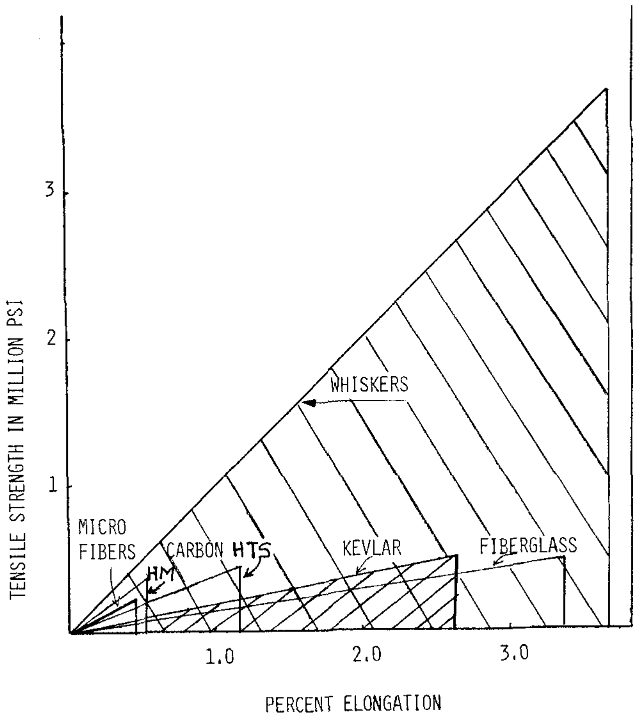

FIG. 30. Comparing the strength and elongation of current reinforcing fibers to those of whiskers.

metal, load-bearing, and structural parts of cars. Figure 29 shows Ford's new, lightweight auto program where a significant number of new areas of the car are being made of reinforced plastics.

The future history of fiber reinforced technology lies in new materials and new processing techniques such as instant cured resins on demand, reinforced with superstrong nonfriable fibers that withstand processing procedures without breaking.

"Blue Sky"

Currently the high strength reinforcing fibers being used have strength in the order of 400,000 psi (Fig. 30). It is expected that by the mid-1980s submicron whiskers with strengths of over 4 million psi will become commercially available. They will give an order of magnitude increase in reinforcement potential. Beyond that, experimental fibers called cobweb whiskers (Fig. 31), are 200 Å in diameter

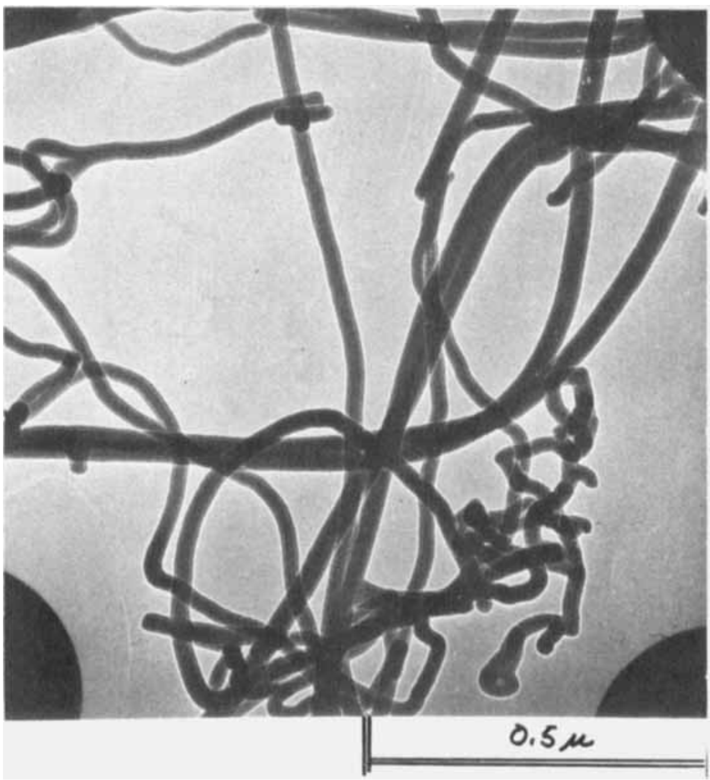

FIG. 31. Experimental fiber called "cobweb" fiber with estimated diameter of about 200 Å.

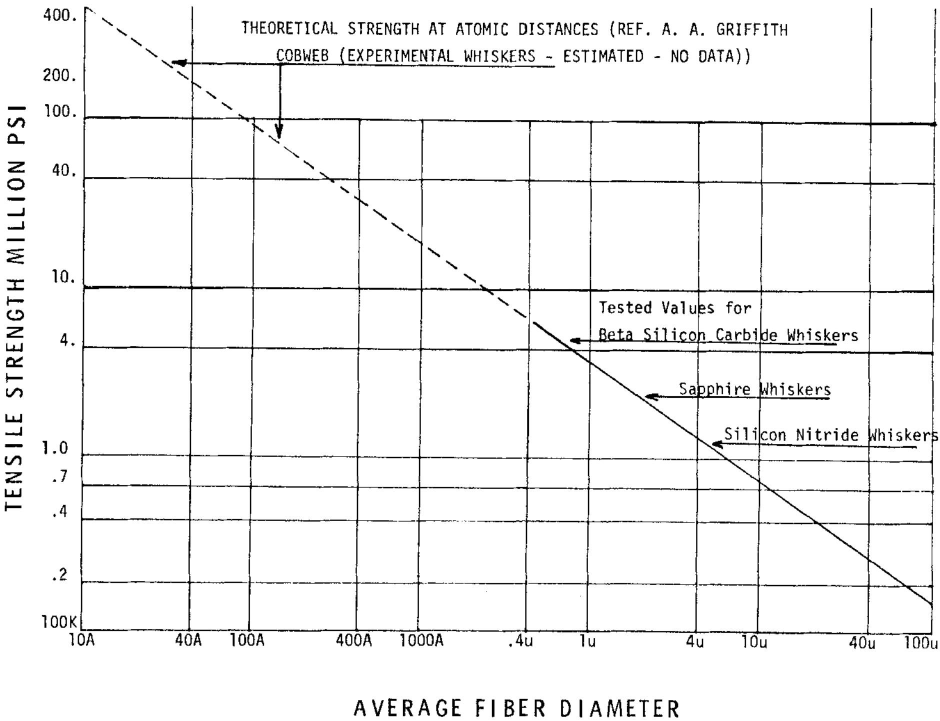

FIG. 32. Tensile strength generally increases as the fiber diameter decreases. This relationship is used to project very high strengths for "cobweb" fibers.

and are estimated to have a strength of about 40 million psi (see Fig. 32), or two orders of magnitude above the current reinforcements. As these new fibers become available, the reinforced plastics industry will take on a whole new prospective in growth.

CHRONOLOGY OF EVENTS

1845. A. P. Critchlow developed Florence (shellac) compound.

1858. B. C. Brodie reported first synthesis of diacyl peroxide, benzoyl peroxide. This peroxide was also the first synthetic peroxide produced commercially.

1859. Butlerov described formaldehyde polymers.

1862. Baldwin's compression mold patented.

1867. George A. Waters, Troy, N.Y., first laminated boat - manila paper and glue, 13 ft long, 13 in. wide.

1868. Four made for U.S. Naval Academy.

1872. Bayer reported reaction between phenols and aldehydes.

1899. Smith published patent on phenol-formaldehyde composition.

1907. Tech-Art Plastics Company (Loando Rubber Company) molded first phenolic plastics compound.

Hans Lebach molded first acid resistant chemical tank from one-stage phenolic resin and asbestos.

1909. Leo H. Baekeland granted his "heat and pressure" patent for making phenolic resins usable (patent application in 1907).

Westinghouse initiated phenolic laminating.

Cold molded bitumin, phenolic and cement-asbestos introduced.

1910. General Bakelite Company formed: Perth Amboy, New Jersey.

1913. D. J. O'Connor's patent application for plastics laminated sheet to replace moisture-absorbing vulcanized fiber, assigned to Westinghouse (issued 1918).

H. Farber and D. J. O'Connor started Formica Products Company to produce RP electrical insulators.

1916. R. Kemp applied for patent on structural RP elements; U.S. Patent 1,393,541 issued in 1921 and assigned to Westinghouse.

1917. Formica made first contacts with infant radio industry through R&D Communication laminated components produced for U.S. Navy and Signal Corps.

Bakelite-Micarta laminated propeller developed for the War Production Board.

1921. Robert Kemp's U.S. Patent 1,393,541 issued, applied 1917, concerns producing RP parts.

1922. Bakelite Corporation formed by merging General Bakelite Company, Redmanol Chemical, and Condensite Company: trade name Bakelite adopted.

R. Kemp's U.S. Patent 1,435,244 on producing on all RP airplane.

L. V. Redman engineered first plant for Western Electric in producing laminates.

1924. Formica patented decorative laminates.

1926. Formica first to plasticize phenolic laminates.

L. E. Shaw developed transfer molding; patent issued 1928.

CIBA patents aniline-formaldehyde resins.

1927. Benzoyl peroxide was first offered in the United States by Lucidol.

F. J. Stokes introduced both rotary and single punch preform presses for thermosets.

1928. Urea formaldehyde introduced commercially.

1929. Synthane Corporation founded world's largest laminated plastics fabricating plant at that time.

1930. Fiberglass research initiated by Owens-Illinois and Corning Glass Works supposedly when a molten glass rod was being used to apply lettering on a glass milk bottle, fine fiber was blown resulting in the start of the glass wool insulation business.

1931. Patent issued to Formica (urea formaldehyde surface on phenolic-paper core, etc.) which provided major start for Formica decorative laminate business.

Canvas phenolic picker blocks and rayon buckets developed for textile machines.

Toledo Scale Company's research project at Mellon Institute to replace heavy and expensive porcelain in their weighing scales resulted in developing urea resins. The demand for use of urea in scales required Toledo Scale Company to set up a special plastics organization called Plaskon Company.

Pioneering research on glass fibers started by Owens-Illinois at Evansville, Indiana.

Before the end of the year, they designed the Dust-Stop air filter.

1932. A. M. Howald of Toledo Synthetic Products Company molded first urea-formaldehyde Toledo scale housing.

1933. CIBA markets "Cibanite," the aniline-formaldehyde molding materials.

Carlton Ellis patented unsaturated polyester resins.

1935. CIBA patents melamine-formaldehyde resins.

1936. CIBA markets melamine-formaldehyde molding compounds in Europe.

1937. Lauroyl peroxide was first offered in the United States by Lucidol.

Automatic Compression molding patented and introduced commercially by Stokes Machine Company.

Urea-formaldehyde wood glues introduced by Aero Research Ltd. (England); now CIBA.

The Society of the Plastics Industry (SPI) was incorporated.

First production of polyester resin.

Prior to the development of polyesters, high molding pressures had to be used for all laminates. Polyesters can be processed with little or no pressure and give off no by-products (water) when curing.

1938. The Owens-Corning Fiberglas Corporation was formed to manufacture fiberglass.

First epoxy resin patent to Pierre Castan (Swiss); licensed to CIBA.

1939. Bakelite Corporation became part of Union Carbide & Carbon Corporation.

1940. RP industry basically started with the use of fiberglass to reinforce plastics. The electronic needs of World War II for radomes (radar domes protected aircraft radar antennas) required major R&D programs to study materials, manufacture, and design.

Pittsburgh Plate Glass Industries "CR-39 and CR-38," the original low pressure allyl type polyester resins, used with cellulose pulp paper, were commercially molded by King Plastics Company.

Basic work on glass-reinforced plastic materials provides background design data for development of pressure vessels for rocketry.

1941. OCF, Ashton, R.I., plant opened for the manufacture of textile fibers (former silk mill).

Yarn reinforcement of plastics for body armor, radomes, antenna housings, aircraft wing tank liners, and many other components.

General Hap Arnold sent telegram to Wright-Patterson Air Force Base stating that a task force was to be set up so that plastics could be examined with the specific purpose of being used in aircraft wherever possible.

King Plastics Company, Denver, Colorado was given Air Force contract to fabricate first plastics seats using combed and carded cotton fibers impregnated with urea and polyester.

Society of Plastics Engineers (SPE) was founded.

Henry Ford swung an ax on an automobile RP body to demonstrate feasibility of RP for automobiles.

RP contributions to World War II; cotton-phenolic ship bearings, asbestos.

1942. Patent issued to F. J. Stokes for automatic unscrewing of threaded closures and other threaded parts, making possible, for the first time, a fully automatic commercial machine available without a license.

Polyester introduced commercially.

Air Force-Wright Field personnel-recognized problem when curing RP at high pressure. One of first contracts to develop a low pressure curing resin system went to Irving Muskat of Marco Chemical Company, Linden, New Jersey ($150,000 contract). Muskat was previously with Pittsburgh Plate Glass and had worked on low pressure resin systems.

(April 29) Air Force-Wright Field personnel had been visiting many different companies to accelerate activity in developing RP. At that time D. L. Grimes of the Air Force presented to industry an important government announcement during the Society of the Plastics Industry meeting in Hot Springs, Virginia. A program had been set up to cooperate with all of industry in collecting at an accelerated rate data on plastics for aircraft structural use which later would be issued in ANC Bulletins on Design Criteria (to become ANC 17 and 23). There was no question at that time of the importance of this program; namely, alternate materials had to be found which could be used in place of strategic metals (such as aluminum).

First fiberglass boat molded by Bassons. When making the mold, it was logical at that time that no one thought it necessary to use a parting agent. All attempts to release the mold failed and the entire assembly was rolled into the Bronx River.

Dow Corning Corporation made silicone commercially.

Navy replaced all electrical terminal boards on vessels with fiberglass melamine laminates and asbestos melamine.

Owens-Corning Fiberglass Corporation received a $200,000 government contract to evaluate RP.

By the end of this year different fabricators throughout the country were producing important RP parts for aircraft - Uniroyal, Goodyear

Tire and Rubber, Formica, Boeing, Douglas, Grumman, Westinghouse, GM, Swedlow, etc.

Patent on "Redux"–a thermoplastic modified phenol-formaldehyde structural adhesive, was issued to Aero Research Ltd. (England), now CIBA.

Consolidated Papers, Inc. formed a special laminated plastics division to supply the U.S. Government with industrial laminates for use in airplane parts, gliders, glider floors, land mines, and ammunition boxes during World War II.

First laminate of fiberglass (ECC-11-148) with CR-38 and CR-39 low pressure laminating polyesters were produced by Pittsburgh Plate Glass for aircraft, boat, and automobile parts. Cotton fabric with CR-39 laminates produced by Goodyear Aerospace Corporation were used in aircraft fuel cell backing sheet materials.

1943. Arthur M. Howald of Plaskon working with personnel at Wright Field made the first RP honeycomb using large soda straws for the form.

Studies continued examining all types of RP: McDonald Aircraft made a paper product called Mitcherlich which was not affected by water. Later Wisconsin Consolidated Water Power and Paper Company further developed this paper to reinforce resins under Wright Field contracts in conjunction with U.S. Forest Products Laboratory.

Air Force-Wright Field started in-house projects to build primary structural aircraft parts for the following reasons: (1) relief to strategic materials, (2) low weight in RP had potential to produce more efficient structures, (3) good electrical insulation and also transparent characteristics made desirable for radomes.

Fiberglass RP were first conceived, developed, and designed for light airframe structures by the Air Force-Wright Field Structures and Materials Laboartory. After analyzing test results on RP, theoretical calculations indicated that an efficient structure could be designed and fabricated using high strength fiberglass-polyester laminate faces with low density, core material. A survey of available military aircraft was performed to select some structural component which was reasonably well adapted to redesign in a sandwich structure. The aft fuselage of the two-lace Vultee BT-15 basic trainer was selected; made with balsa wood core. The static tests performed in 1943 on the first fabricated fuselage demonstrated the predicted high structural efficiency. From a strength to weight basis, the plastics sandwich structure was approximately 50 percent stronger than either the metal or wood type construction. In addition to its high structural efficiency, the sandwich section showed a remarkable absence of skin buckling under high torsional load.

Reinforced plastic tooling developed by L. Wittman at Republic Aviation.

Pregwood (resin impregnated reinforced wood) used for airplane propellers due to aluminum shortage.

Laminates used in bomb tubes and bazooka barrels.

Copper clad laminates for electronics introduced.

Plaskon Company of Toledo Scale Company was purchased by Libby-Owens-Ford Company (LOF).

1944. First filament winding of RP hoops by Lubin and Greenberg at Bassons Industries.

The Society of the Plastics Industry (SPI) organized the Low Pressure Industries Division.

L. Wittman of Republic Aviation Corporation developed first low pressure thermosetting prepregs. Later merchandized by Fabricon in 1945.

Thermoset composites extruded at Plastics Engineering Company.

Vinyl silicone coupling agent as an adhesive. U.S. Patent 2,513,268 was issued.

Resorcinol-formaldehyde adhesives introduced by Aero Research Ltd. (England), now CIBA.

Cumene hydroperoxide was first produced by Hercules Company.

Eagle wing-radar antennas located below B-29 airplane main wing eroded and were damaged during flights through Pacific rains; resulted in expediting developing elastomeric, rubber type, rain erosion coatings applied over radome and other RP surfaces.

(March 24) The BT-15 airplane with the plastics sandwich fuselage was first flown at Wright-Patterson Air Force Base. This was considered first successful major structural component of an airplane using RP to be developed and flown.

(April) Aircraft RP sandwich wings using RP wrapped cellular cellulose acetate core with RP skins for AT-6 were designed. Actual fabrication of the first wing took place 1945 in the engineering shops of the Air Force Laboratory in Dayton; static tests 1946; and finally flight tests 1953.

Began development of commercial F/G reinforced polyester plastics.

Boat hulls introduced by Winner Manufacturing.

First production of FRP hulls in volume.

Plastics Engineering Co. extruded Baybolla barrels of cloth-filled phenolic. First commercial thermoset extrusion of RP.

1945. Experimental car body produced under OCF sponsorship.

L. S. Meyer of Western Products made first production RP honeycomb by using soda straws to index corrugated sheets.

Benzoyl peroxide paste formulations were first offered by Lucidol.

Virgil Meharg and Paul Zotter introduced dielectric heating.

Cloth-phenolic for high strength switchgears, cotton flock-phenolic M-52 fuses, lead-phenolic frangible bullets, canvas-phenolic gunstocks, cotton-asbestos-phenolic brake linings, acetate-cotton bayonet scabbards, cotton cloth-phenolic radio direction finders, phenolic-plywood trainers, Mosquito British bombers, and virtually thousands more.

1946. Considered as the year of the commercial introduction of FRP.

FRP casting and fly fishing rods introduced.

First automatic injection molding of RP by Dr. A. M. Howald at Plaskon.

Patent application for first fiberglass spray technique (centrifugal spraying for molding RP pipe) by Lubin, Minikes, and Martin.

First molding pf production fiberglass parts in low cost matched metal molds by L. Wittman at Republic Aviation Corporation.

Epoxy resins, called Araldite, introduced by CIBA at Swiss Industries Fair.

Filament winding process patented by R. E. Young.

Rocket motor case developed by R. E. Young.

Advent of fiberglass-polyester small boats for Navy usage.

1947. Glass Fibers, Incorporated was formed by Randolph Bernard.

Diisopropylperoxydicarbonate was first offered commercially by Pittsburgh Plate Glass Industries.

Dr. I. Muskat developed first thixotropic resins at Marco Chemical.

On. U.S. Navy Bureau of Ordnance contract, R. E. Young at M. W. Kellog designed a machine and began the first filament winding operation using fiberglass-polyester on rocket motors; also manufactured filament wound pipe for shipboard use.

Consoweld Corporation introduced 4 feet by 4 feet high pressure laminated panels.

Epoxy introduced commercially in the United States as an adhesive.

Vinyl silicone coupling agent presented in U.S. Patent 2,513,268.

R. Steele of Hexcel made first production of RP honeycomb using bonded stack expansion process.

RCA built first T.V. tuner circuit using printed inductors for Halicrafters.

Copper-clad materials for commercial use developed by Synthane.

1948. (March 9) Air Force awarded Douglas Aircraft Company contract (first of its application type) to design and fabricate for the C-54A flying laboratory airplane outer wing panel. RP replaced metal in a feasibility study to use integral wing antenna which would also be part of the structure.

The Low Pressure Industries Division of SPI changed its name to the Reinforced Plastics Division.

U.S. Navy produced first RP fiberglass-polyester boats, 28 feet long, built by Winner Manufacturing Company (by 1968 the Navy had over 2,000 of these type boats in use).

Roger White and Larry Seidel of Glastic Corporation made and molded first fiberglass-polyester premix.

(March 11) Air Force started project to design, develop, and fabricate primary structural aircraft parts made of RP for use on supersonic aircraft and missiles.

First attempts at injection molded FRTP were in toilet seats for Church Seat Company (best seat in the house).

First substantial use of matched metal dies.

Low-cost, one piece FRP chair by American Transportation.

1949. Earliest commercial parts - brusholder stud for Reliance Electric Railway and mine locomotive applications and heat - resistant coil for an electric motor field coil.

Installation of first FRP radome for weather Bureau station at Sault Sainte Marie, Michigan.

U.S. Plywood and Dagional produced first large machines for the continuous production of filament wound tubes.

Molded Resin Fiber Company received the first mass production contract in using matched metal molds and hydraulic presses; produced 1,000 trays per day.

"Lupersol DDM," the first commercial methyl ethyl ketone peroxide was offered by Lucidol.

Crucible Steel Corporation patented "Formold," a steel used to produce dies for compression molding.

1950. Fiberglass-phenolic commercial molding compounds produced.

Triallyl cyanurate (TAC) first basic patent by Kropa was granted to American Cyanamid; used to produce heat resistant RP laminates.

Continuous RP sheet production lines were operating to meet principally military demands to produce protective backing sheets for aircraft self-sealing elastomeric fuel tanks.

RP helicopter and aircraft blades developments emphasized by Bell Aircraft, Kaman Aircraft, Curtiss-Wright, Hamilton Standard, etc. due to unique RP fatigue characteristic.

RP armor plate development programs applicable to aircraft conducted.

RP dropable aircraft fuel tanks developed and produced; extensively used in Korea.

Lockheed Aircraft Corporation's Constellation airplane used the popular and large-production 80 inch long radome on the top side as well as large, tub-shaped under-belly radomes.

22 FRP boats exhibited at the New York Boat Show.

First successful commercial applications of injection molded FRTP (polystyrene tape recorder tape reels), over a million produced.

1951. Kaiser-Darrin introduced first hand lay-up production sports car with all FRP body, had sliding doors on Henry J. chassis. Sold for $3668, Cadillac $3500, 70 were made.

Development of the first workable chopped for producing chopped strands.

Automatic preform machines developed by Ivan Brenner (ex-OCF).

FRP chair designed by Charles Eames for Herman Miller wins Museum of Modern Art low-cost furniture competition.

Ferro, Pittsburgh Plate Glass, Libby-Owens-Ford Glass, and Gustin-Bacon were all granted licenses by Owens-Corning Fiberglas to produce fiberglass.

First chrome complex patent issued to R. K. Iler–basis of DuPont's "Volan" finishes.

First allylsilane glass size patented by Robert Steinman; predecessor of silane coupling agents.

International Standards Organization established a technical committee on plastics (ISO/TC61).

1952. First fiberglass RP landing mats developed by Army at Ft. Belvoir (S. Goldfein).

Start of era for large rocket motor production, such as Matador.

FRP introduced in light weight pipe for use in oil wells and distributing lines (centrifugal cast).

OCF went public with 1.5M shares.

Storage tanks.

Translucent corrugated construction panels.

Protective body armor for the armed forces.

500 FRP parts on the B047 Strato-bomber, from nonwoven mats or chopped strand preforms.

General purpose polysters introduced by American Cyanamid.

1953. General Motors launched an exploratory program with its Chevrolet Corvette all FRP body.

In this first production year of the Corvette, 300 were produced using glass fabric vacuum bag, aerospace technology.

The success of the Corvette pointed up the advantages of FRP in the fabrication of large complex shapes in relatively low volume.

12,000 lb FRP fairwater installed on submarine Halfbeak.

Mobile Plastics Division of Carlyle Corporation produced the first preimpregnated roving.

1954. Ford introduces FRP as stationwagon trim, genuine artificial wood that turned white with age.

Also used in other auto and truck components, prototype models, and low-cost, efficient tooling.

Ford Thunderbird has removable FRP hard top.

1955. FRP guy strain insulators developed for use by electric utilities.

Start of fiberglass-polyester automobile production runs made on the Corvette body.

Winchester made first fiberglass-epoxy shot gun barrels.

Early ablation studies on re-entry from space travel showed outstanding characteristics for phenolic-fiberglass and phenolic-asbestos on Viking rocket flight tests.

NOL (Naval Ordnance Laboratory) Ring and initial test methods first used in RP R&D work.

First use of plastics as ablative materials, General Electric Company.

Taylorcraft Model 20 airplane used RP in wings, engine cowling, doors, seats, fuel tanks, instrument panels, fuselage skin from nose to the fin trailing edge, etc.

Vertol H-21 Helicopter produced, lower cost, equally efficient RP in fuselage.

1956. First plastics re-entry nose cone made by Cincinnati Developmental Laboratories from phenolic resin and asbestos fiber.

First plastics nose cone on Vanguard successfully flew with phenolic-asbestos in monocoque construction.

First filament wound rocket motor flew on 3rd stage Vanguard missile (Grand Central Rocket).

Fiberglass-epoxy laminates widely adopted for printed circuit boards.

General Electric pioneers use of Fiberglas mat and polyester resin in switch gear, phase barriers, automatic shutters, and similar products which require great strength and high heat resistance.

An interesting new type of reinforcement was introduced, Flakeglas, composed of extremely thin glass flakes, now under test for a variety of end uses.

1957. FRP radomes used in construction of the DEW line early warning system, far above the Arctic Circle.

First U.S. satellite "The Explorer" contained FRP parts (instrument carrying frame and coupling ring).

FRP superstructure on the world's first atomic submarine "Nautilus."

FRP in B-58 "Hustler" and B52 "Strato-Fortress."

Monsanto's FRP "House of the Future" at Disneyland.

FRP public transit bus seats and FRP.

FRP luggage introduced.

First re-entry nose cone recovered from Pacific used fiberglass on melamine Redstone missile.

First operational ablative nose cone that flew on Jupiter missile (IRBM) used refrasil-phenolic.

1958. First missile (ICBM) nose cone used refrasil-phenolic.

LOF Glass Fibers, Incorporated was sold to Johns-Manville Corporation.

Cycloaliphatic epoxy resins patents to CIBA.

First commercial production of graphite fibers from rayon.

Piper Aircraft started investigation of RP for primary structures RP airplane which flew in 1962.

FRP lifeboats approved by U.S. Coast Guard as equipment for American flag passenger vessels and freighters.

Continuous rolls of FRP laminate produced as liners for bins, tanks, freezers, refrigerated travel trailers, truck bodies, and freight cars.

90% of all fishing rods are FRP.

Out of 450 boats, 129 were FRP in N.Y. Boat Show.

FRP gutters and down spouts, "Permodrain."

Texaco Incorporated reports the strength and stiffness of boron fibers.

1960. Boeing 727 jet airplanes each contained 5,000 pounds of RP lower cost parts than metal parts and 33 percent lower in weight.

Douglas DC-8 jetliners each contained 2,000 pounds of RP–which included unique RP structural parts of spar and vertical tail section.

High strength and high modulus fibers being developed: S-glass, boron, over 1 million psi glass tensile strength, over 50 million psi fiber moduli, etc.

Grumman Aircraft Corp. Hawkeye E-2A used rotating 24 feet diameter radome located above wing.

Mississippi State University Marvelette airplane with RP smooth surface structure used in conducting laminar boundary layer control flight tests.

Piper Aircraft Company flew RP airplane fiberglass-polyester skins with paper honeycomb core.

The Dow Chemical Company started building the Windecker fiberglass-epoxy RP wing for a monocoupe, low-wing airplane.

Admiral Levering Smith from the Special Project Office of the U.S. Navy handed down a decision to develop filament wound fiberglass-epoxy motor cases for the Polaris missile which later proved highly successful on strength to weight ratio, reliability, and cost advantages in comparison to steel types.

First of the world's largest laminating presses installed at Consoweld Corporation. It was the first press to produce 180,000 square feet of laminates daily. The press stands 28 feet high and weighs 300 tons.

Marine Design Manual for fiber glass reinforced plastics published by Gibbs and Cox.

Hatteras 41 and Bertram 31 introduced this year. First real inroads for FRP in the firmly entrenched wooden power cruiser business.

UCC Carbon Fiber Research started.

1961. FRP bucket and boom introduced provided a safe method of working on energized high voltage lines.

Corvette introduces the "String-Ray."

First experimental graphite with a high modulus of 24×10^6 psi from polyacrylonitrile (by A. Shindo).

First commercial production of continuous graphite filament (modulus 60×10^6 psi).

1962. First rudders for submarines by Republic.

Studebaker introduces the AVANTI. First producer of a hardtop production car with an all FRP body designed by Raymond Loewy. Floor pan is the largest FRP part ever put into production in U.S.

FRP shower stall.

White Truck introduces series 5000 tilt cabover engine model. First all FRP truck cab in U.S. 30% weight reduction at no sacrifice of strength.

Introduction of all FRP Dodge motor home.

S-glass introduced. High-tensile strength, high-temperature resistant, high-modulus glass to meet extreme requirements of space applications.

Polaris A-3 submarine launched ballistic missile, included FRP filament wound motor cases, nozzles, and electrical connectors.

Filament winding adopted for forming corrosion-resistant pipes, tanks, pressure vessels, and other commercial products. American Coat Corp. "Bondstrand" pipe.

FRP in heat shields for re-entry in the man-in-space Mercury projects.

275 individual FRP parts in Sikorsky HSS-2 helicopter.

1963. U.S. Navy submarine "Fairwater" placed in service during 1952 successfully completed eleven years of service using different RP primary parts.

General Schriever initiated project Forecast, the first program for the development of boron composites.

First injection molded FRTP part for production automotive applications - instrument panel for Cadillac.

First commercial source of whiskers from Thermokinetic Fibers, Inc.

1964. 300 ft British minesweeper designed.

First book on Filament Winding: its Development, Manufacture, Applications, and Design by Rosato and Grove. Wiley.

Conical shape filament wound motor-case developed for Sprint (2 stages) missile using "S" glass filaments.

LNP Corporation introduces the first fully and evenly dispersed fiberglass reinforced thermoplastics using nylon 6/6.

Commercial injection molded fiberglass reinforced thermoplastics started for military weapon systems.

1965. Advanced composite section created at AFML Wright Field under G. Peterson's direction.

Gibbs and Cox completed Navy feasibility study using RP on minesweepers.

Boron filaments become available to the public.

First RP structural aircraft fuselage applications for service at 600°F in F-111 aircraft (Grumman/General Dynamics).

U.S. "walks in space." Lt. Col. Edward White during flight of Gemini IV. FRP was there; FRP helmet, filament wound altitude control gun, and FRP survival kit.

Comet cyclone produced with an FRP hood.

G.E. introduces FRTP (polypropylene) pump, motor support, jet arms, screen and hose fittings for home dishwashers.

Stadium seating introduced.

1966. OCF above-ground chemical tanks introduced.

80 FRP components on 1967 model year autos.

Introduction of the fiberglas belted bias tire by Armstrong Rubber Co. (the principal supplier to Sears).

First full scale balast tank for Px-15 submersible by Grumman.

1967. Windecker Research Incorporated, Midland, Texas, flight-tested the first relatively all RP single-wing airplane designed (after 7 years) specifically to be made of fiberglass-epoxy.

Goodyear introduces the "polyglas" bias belted passenger car tire.

FRP golf club "Black Knight," Gary Player wins U.S. Open.

Yankee Stadium goes to FRP seats–goodbye splinters.

S-2 Glass (Commercial S-Glass) introduced.

Bob Seagren breaks world pole vault record with 17 ft, 9 in. with FRP pole.

DuPont introduced Fybex a new "Micro Fiber."

U.S. Navy starts R&D in using RP on minesweepers.

Molded RP bathroom displayed at Canada's Expo 67.

The Society of the Plastics Industry (SPI) changed the name of its Reinforced Plastics Division to Reinforced Plastics/Composites Division.

First Dow Chemical patented "black box" made commercially available. It fed proportional amounts of chopped fiberglass and resin into an injection machine where the screw provided the mixing and blending.

1968. Reed-Prentice obtained Dow Chemical's "black box" to develop and market the fiberglass-resin proportional mixer used with injection machines. In place of the name "black box," it became known as the CMB (Custom Material Blender).

Boeing's SST design includes use of over 6,000 pounds of RP and over 6,000 pounds of unreinforced plastics.

Aircraft R&D continues to use practically all types of plastics and provide an important testing ground for new plastics in order to meet different requirements. Rosato estimated consumption for U.S. aircraft in 1968 was at 50 million pounds ($1/2 billion dollar value in plastics) of which half was in unreinforced and half in reinforced plastics.

LNP comprehensive creep and fatigue characteristics for reinforced thermoplastics.

First SMC automotive applications.

Station wagon air deflector, Chrysler.

First FRTP auto finder liners Ford or GM.

Hatteras Yacht introduces kits for 60 ft FRP yacht, the largest production model in the U.S.

Filon develops continuous sheetmaking machine for transparent laminated flat and corrugated sheets.

1969. A leading brassiere manufacturer replaces metal underwire with FRP.

Hatteras Yacht produces 8 of their new 74 ft all FRP shrimp trawlers.

Sears introduces their 12 ft Gamefisher car-top boat. First match metal die-molded production boat.

FRP entry in the car top boat market.

First high volume automotive applications. Pontiac SMC front end, fender extenders, and lamp housing, Olds Toronado SMC valance panel.

Apollo 11 "The Eagle Has Landed." Neil Armstrong becomes the first man to stand on the moon. FRP was there.

1970. OCF began merchant sales of polyester resins, general purpose polyesters for the tub/shower market.

OCF installs high voltage out-of-door test stations for FRP electrical components.

10,000 FRP underground tanks in use.

Concrete curing forms and silos.

G.E. introduces "Carry Cool" room air conditioner. SMC molding facility was included in design of this part so that they could actually manufacture it. The part weighs 7 pounds and combines the base pan, bulk head, and carrying handle in one SMC molding.

FRP breaks into the business equipment market with a 3 piece SMC housing for the NCR 250 cash register.

Pontiac has SMC front ends on five models.

Thermoplastic polyester commercially produced.

First glass fiber reinforced thermoplastic polyester (PET) compound demonstrating facile processing (Celanese).

1971. Apollo 15. First use of Lunar Roving Vehicle (FRP fenders).

1972. Advances in RP compounding using twin screw extruder using continuous roving, Werner & Pfleiderer.

Total shipments of FRP composites exceed 1 billion pounds (1.2 billion lb).

OCF large diameter pipe and manholes.

DuPont introduces Avamid Fiber Kevlar.

1973. Introduction of the all-glass radial tire by Mohawk Rubber Co.

Milewski introduces concept of micropacking of fibers and spheres to save resin.

All glass-thermoset polyester bathrooms mass produced.

Glass fiber reinforced polyphenylenesulfide, Phillips Petroleum.

1974. Fedders introduces their "Pickup" room air conditioner utilizing an SMC clam shell case and interior.

1975. Foamed polyester introduced.

Primer on injection moldable RP, LNP Corp.

1976. Plastic pencils: Empire Pencil Co. introduced a coextrusion of glass fiber filled ABS foam with a skin over a lead core. Beol Co. uses coextruded 2% glass fiber-filled polystyrene with a yellow skin over a lead core.

Franklin Fiber, low-cost calcium sulfate microfiber introduced experimentally by Certain Teed Corp.

1977. Major inroads made in R&D automotive programs in the use of carbon fiber composites to reduce cost and weight in automobiles.

1978. Reduced British airship gondola with reinforced DuPont Kevlar 49 aramid fiber with epoxy in place of traditional aluminum, Aerospace Developments Ltd., England.

Total shipments of FRP composites expected to reach 2.01 billion pounds.

Boeing adopts S-2 glass for aircraft flooring in all 700 series aircraft (727, 737, 747, 760, etc.).

PMF, a low-cost short fiber is introduced by Jim Walter Resources.

Helicopter blades in Boeing Vertol, a highly engineered hybrid-titanium, S-glass prepreg, Nomex honeycomb, glass or Kevlar skin. A very dynamic application of S-glass used for impact and dynamic fatigue resistance.

150 ft FRP windmill blades for wind energy.

IBM adopts SMC housing, base, and flip-up for 4 models of their "Selectric" typewriter.

Hull Corp. introduces BMC injection machine.

IHC introduced prototype of all RP body for the "Scout.:

1979. Metal fiber and metal-coated fibers are introduced to electromagnetic shield applications.

Predictions for future use of nonglass fiber RP, by 1985, include: at least 4 million lb of graphite fiber, aramid fibers to 3 million lb (currently at $\frac{1}{2}$ million lb), and 45,000 lb of boron fiber (currently at 5,000 lb). Annual market for graphite fiber could reach 100 million lb based on automotive potential.