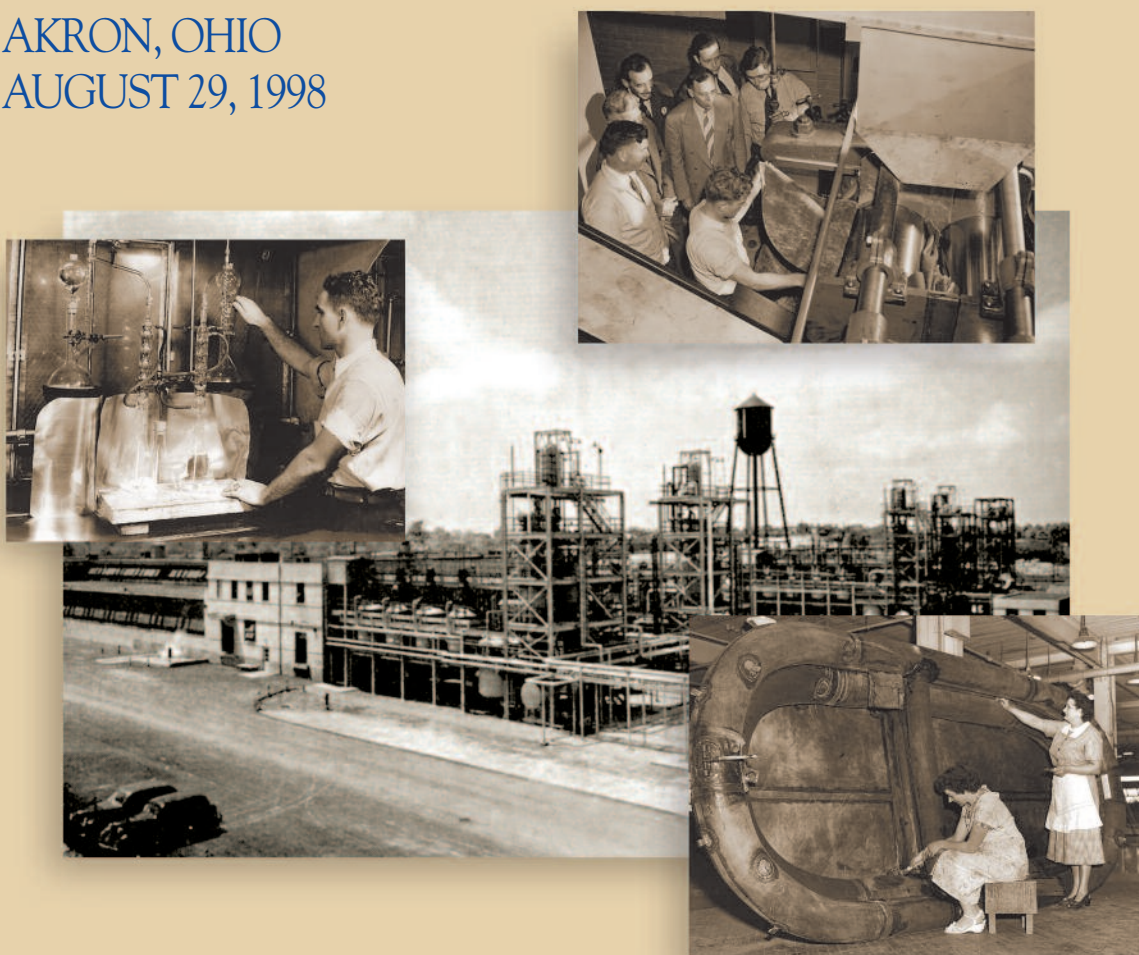


A NATIONAL HISTORIC
CHEMICAL LANDMARK

UNITED STATES SYNTHETIC RUBBER PROGRAM, 1939-1945

AKRON, OHIO
AUGUST 29, 1998



AMERICAN CHEMICAL SOCIETY
Division of the History of Chemistry and
The Office of Communications



The first U.S. government synthetic rubber plant to go into production, Akron, OH, April, 1942.

This booklet commemorates the designation of the United States synthetic rubber program, 1939–1945, as a National Historic Chemical Landmark. The designation, which recognizes the research, development, and early production of synthetic general purpose GR-S rubber, was conferred by the American Chemical Society, a nonprofit scientific and educational organization of more than 155,000 chemists and chemical engineers. A plaque marking the event was placed at The University of Akron on August 29, 1998. (Additional plaques were presented to the five companies listed below that participated in the development of GR-S rubber.) The inscription reads:

When the natural rubber supply from Southeast Asia was cut off at the beginning of World War II, the United States and its allies faced the loss of a strategic material. With U.S. government sponsorship, a consortium of companies involved in rubber research and production united in a unique spirit of technical cooperation and dedication to produce a general-purpose synthetic rubber, GR-S (Government Rubber–Styrene), on a commercial scale. In Akron and other U.S. locations, these companies, in collaboration with a network of researchers in numerous government, academic, and industrial laboratories, developed and manufactured in record time enough synthetic rubber to meet the needs of the U.S. and its allies during World War II:

The Firestone Tire & Rubber Company
The B. F. Goodrich Company
The Goodyear Tire & Rubber Company
Standard Oil Company of New Jersey
United States Rubber Company

On the cover (clockwise):

Synthetic rubber production; war plant workers with rubber life raft; U.S. government plant operated by The Firestone Tire & Rubber Company; B. F. Goodrich chemist G. L. Browning.

Background: Synthetic rubber tire production line, United States Rubber Company plant, Detroit, MI.

Acknowledgments:

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THE QUEST

The quest to synthesize materials that can be substituted for naturally occurring substances has long been a challenge to chemists. By 1914, natural dyes from plants had been replaced by synthetic dyes derived from coal tar, celluloid had taken the place of ivory, and Bakelite was replacing insect-based shellac. Nonetheless, these products were produced on a relatively small scale.

By contrast, natural rubber was a commodity of vast economic and military importance. Automobiles, a key element of American social life, could not run without rubber tires, and by the 1930s, the U.S. automotive industry had grown rapidly to a size unmatched anywhere. A modern nation could not hope to defend itself without rubber. The construction of a military airplane used one-half ton of rubber; a tank needed about 1 ton and a battleship, 75 tons. Each person in the military required 32 pounds of rubber for footwear, clothing, and equipment. Tires were needed for all kinds of vehicles and aircraft.

The American rubber industry became the largest and the most technologically advanced in the world. By the late 1930s, the United States was



Synthetic rubber production, 1942.

using half the world's supply of natural rubber, most of it coming from Southeast Asia. Shortages of natural rubber caused by the advent of World War II led the U.S. government to embark on a program to produce a substitute for this essential material—quickly and on a very large scale. There was a real danger the war would be lost unless American scientists and technologists were able to replace almost a million tons of natural rubber with a synthetic substitute within 18 months.

To work this industrial and scientific miracle, the U.S. government joined forces with the rubber companies, the young petrochemicals industry, and university research laboratories. The resulting syn-

thetic rubber program was a remarkable scientific and engineering achievement. The partnership of the government, industry, and academe expanded the U.S. synthetic rubber industry from an annual output of 231 tons of general purpose rubber in 1941 to an output of 70,000 tons a month in 1945.

The impact on the rubber industry proved to be permanent. Today 70% of the rubber used in manufacturing processes is synthetic and a descendant of the general purpose synthetic GR-S (government rubber–styrene) produced by the United States in such great quantity during World War II.



B. F. Goodrich chemist G. L. Browning conducting a synthetic rubber experiment.

Beginnings

Michael Faraday had shown in 1829 that rubber had the empirical formula C_5H_8 . In 1860, Greville Williams obtained a liquid with the same formula by distilling rubber; he called it “isoprene”. Synthetic rubber technology started in 1879, when Gustave Bouchardat found that heating isoprene with hydrochloric acid produced a rubberlike polymer. However, Bouchardat had obtained isoprene from natural rubber; the first truly synthetic rubber was made by William Tilden three years later. Tilden obtained isoprene by cracking turpentine, but the process of converting it to rubber took several weeks. In 1911 Francis Matthews and Carl Harries discovered, independently, that isoprene could be polymerized more rapidly by sodium.

In 1906 scientists at the Bayer Company in Germany embarked on a program to make synthetic rubber. By 1912, they were producing methyl rubber, made by polymerizing methylisoprene. Methyl rubber was manufactured on a large scale during World War I, when a blockade halted the import of natural rubber to Germany. Because methyl rubber was an expensive and inferior imitation, production was abandoned at the war's end.

Through the 1920s, synthetic rubber research was influenced by fluctuations of the price of natural rubber. Prices were generally low, but export restrictions of natural rubber from British Malaya introduced by the British in 1922, coupled with the resultant price increase, sparked the establishment



Goodyear rubber plant worker with aircraft tire, 1940.

of modest synthetic rubber research programs in the Soviet Union, Germany, and the United States between 1925 and 1932.

Researchers at I. G. Farben, a German conglomerate that included Bayer, focused on the sodium polymerization of the monomer butadiene to produce a synthetic rubber called “Buna” (“bu” for butadiene and “na” for natrium, the chemical symbol for sodium). They discovered in 1929 that Buna S (butadiene and styrene polymerized in an emulsion), when compounded with carbon black, was significantly more durable than natural rubber.

carbon black, was significantly more durable than natural rubber.

Origins of the Synthetic Rubber Industry in the United States

Because of its working relationship with I. G. Farben, the giant oil company Standard Oil of New Jersey (now Exxon Chemical Company, a division of Exxon Corporation) was an important go-between in the transatlantic transfer of synthetic rubber technology. In the early 1930s, chemists at Jersey Standard began research and development on the production of butadiene from petroleum. Their work involved dehydrogenation, a reaction that removes hydrogen atoms from hydrocarbon molecules. The discovery of catalysts to accelerate the reaction, along with purification procedures and process modifications, allowed large-scale production of butadiene. The company, under the leadership of Frank A. Howard, entered into agreements with I. G. Farben and, through the Joint American Study Company, exchanged technical information on synthetic rubber and other developments. Jersey Standard also had limited development rights for Buna S and administered the patents in the United States after the outbreak of war in Europe in 1939. Because GR-S is similar to Buna S, this technology proved crucial to solving the rubber crisis facing the United States when the war spread worldwide.

In the United States, research and development to produce an all-purpose substitute for natural rubber was dominated by the big four rubber companies, The Firestone Tire & Rubber Company (now Bridgestone/Firestone, Inc.), The B. F. Goodrich Company, The Goodyear Tire & Rubber Company, and United States Rubber Company (now Uniroyal

Chemical Company, Inc., a subsidiary of Crompton & Knowles Corporation). Their collective technical knowledge was significant to the successful outcome of the synthetic rubber program.

The work of two Russian scientists employed by United States Rubber, Alexander D. Maximoff and Ivan Ostromislensky, had resulted in 1920s patents for emulsion polymerization of butadiene and also of styrene. B. F. Goodrich Company scientists, under the direction of chemist Waldo L. Semon, built a 100-pound-per-day pilot plant to copolymerize butadiene with methyl methacrylate to produce a rubber for tire applications. The resulting product, “Ameripol”, was introduced in 1940. Ray P. Dinsmore of Goodyear patented “Chemigum”, a synthetic rubber produced in Akron, Ohio, that same year. James D. D’Ianni, also working at Goodyear, did extensive research on synthesizing a variety of monomers that could be polymerized with butadiene. John Street directed the Firestone program for polymerizing butadiene and styrene and built a synthetic rubber pilot plant for tire applications. Still, natural rubber remained the mainstay of U.S. manufacturing.



Sheets of dried synthetic rubber (left) and dried natural rubber (right).

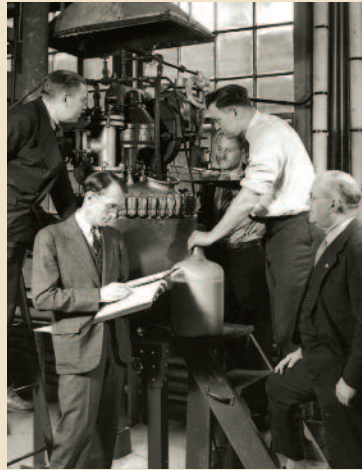
World War II Rubber Supply Crisis

President Franklin D. Roosevelt was well aware of U.S. vulnerability because of its dependence on threatened supplies of natural rubber, and in June 1940, he formed the Rubber Reserve Company (RRC). The RRC set objectives for stockpiling rubber, conserving the use of rubber in tires by setting speed limits, and collecting scrap rubber for reclamation.

The onset of World War II cut off U.S. access to 90% of the natural rubber supply. At this time, the United States had a stockpile of about 1 million tons of natural rubber, an annual consumption rate of about 600,000 tons per year, and no commercial process to produce a general purpose synthetic rubber. Conserving, reclaiming, and stockpiling activities could not fill the gap in rubber consumption.

After the loss of the natural rubber supply, the RRC called for an annual production of 400,000 tons of general purpose synthetic rubber to be manufactured by the four large rubber companies. On December 19, 1941, Jersey Standard, Firestone,

Goodrich, Goodyear, and United States Rubber signed a patent-and-information-sharing agreement under the auspices of the RRC.



Waldo L. Semon (2nd from the right) and other B.F. Goodrich scientists, 1940.

The situation became even more critical as the need for rubber for the war effort increased. With stocks of rubber dwindling and conflicts arising over the best technical direction to follow, Roosevelt appointed a Rubber Survey Committee in August 1942 to investigate and

make recommendations to solve the crisis. The committee, headed by financier Bernard M. Baruch, also included scientists James B. Conant, president of Harvard University, and Karl T. Compton, president of Massachusetts Institute of Technology.

In the remarkably short time of one month, Baruch's committee made its recommendations, two of which were critical to solving the rubber crisis: the appointment of a rubber director who would have complete authority on the supply and use of rubber, and the immediate construction and operation of 51 plants to produce the monomers and polymers needed for the manufacture of synthetic rubber. William M. Jeffers, president of the Union Pacific Railroad, served as the first rubber director, with Bradley Dewey, president of Dewey and Almey, as deputy, and Lucius D. Tompkins, a vice president of United States Rubber Company, as assistant deputy.

Cooperative Efforts Solve the Rubber Crisis

The technology chosen for synthetic rubber production was based on Buna S research because Buna S could be mixed with natural rubber and milled on the same machines, and because the raw materials (the monomers) were available. This rubber was particularly suited for tire treads because it resisted abrasive wear; and it retained sharper impressions in molds, calender rolls, and extruders than natural rubber. However, the synthetic rubber

Natural Rubber

Natural rubber has been known for centuries. The French explorer Charles-Marie de la Condamine reported in 1745 that South American Indians used it for footwear and bottles. It is obtained primarily from the latex of the rubber tree, which is native to South America.

Rubber gained its name after its introduction to Europe and its use for erasing pencil marks. It was soon called (Indian) "rubber".

The first major use for rubber was balloon cloth, fabric coated with rubber dissolved in turpentine. In 1823, Charles Macintosh, using naphtha, a better solvent, laminated sticky rubber cloth and fabric together to make raincoats.

Although rubber captured the public's imagination, there were problems. Rubber froze rock hard in the winter and melted in the summer. In the early 1830s, there was great demand for goods made from this waterproof gum, but the "rubber fever" ended abruptly because of product failures.

It was Charles Goodyear who discovered a way to cure natural rubber to make it more useful. Working on a kitchen stove in 1839, he mixed rubber with sulphur and white lead. This process, vulcanization, made rubber more resistant to changes in temperature and accelerated the growth of the rubber industry.

By 1910, Asian rubber plantations, started from seeds brought from the Amazon Basin, displaced rubber from the wild trees of South America and became the primary source for a growing market.

was more difficult to make, had less tackiness, and required more adhesive in making a tire than natural rubber. These problems had to be overcome to produce a reliable general purpose rubber.

“We would be blind if we did not see the efforts now in progress on the part of many companies to have a part in the development of a large new industry with vast post-war possibilities.”

Report of the Baruch Rubber Survey Committee, September 10, 1942

On March 26, 1942, the representatives of the companies and the U.S. government agreed upon a “mutual recipe” to produce the GR-S rubber. The recipe consisted of monomers butadiene (75%) and styrene (25%), potassium persulfate as a catalyst or initiator, soap as an emulsifier, water, and a modifier, dodecyl mercaptan. Because GR-S required different compounding conditions, accelerators, antioxidants, and types and amounts of carbon black than natural rubber, the program’s leaders realized that a research and development program would be necessary to solve the existing and potential problems of GR-S manufacture.

Robert R. Williams of Bell Telephone Laboratories organized and coordinated the rubber industry research effort, which included participation by the National Bureau of Standards, Bell Labs, and such major research universities as the University of Illinois, University of Minnesota, and University of Chicago. The first of many Copolymer Research Committee meetings was held December 29, 1942, in Akron, Ohio, to share the latest information among the organizations working on the various aspects of synthetic rubber research. In addition to representatives from the government, the major companies, and universities, there were contributors from Columbian Carbon Company, Case School of Applied Science (now Case Western Reserve University), Princeton University, and The University of Akron. The affiliations of the attendees at this meeting demonstrate the wide participation in the program. Phillips Petroleum, General Tire, the Polymer Corporation, and Cornell University delegates were at later meetings.

During the combined effort, the companies shared the findings of more than 200 patents. Participating U.S. scientists and engineers improved the polymerization process, produced modifiers that allowed existing processing equipment to equal natural rubber production rates, specified carbon black grades for specific applications, and modified butadiene production to improve efficiency. University

laboratories developed better analytical methods to achieve better quality control and performed fundamental research on the mechanism of GR-S polymerization and the chemical structure of rubber. Academic and industrial contributors clarified the factors that influenced the polymerization rate, polymer molecular weight, and weight distribution.

GR-S Rubber Production

The rubber companies had the technology and the responsibility to build the plants to produce synthetic rubber. The government provided an equally important component, the capital. W. I. Burt, a B. F. Goodrich engineer, chaired the committee that designed and built the first government GR-S plant. Walter Piggot, also from Goodrich, chaired the engineering committee for GR-S production.

Several plants were scattered across the country, some for polymerization, others for the production of the monomers. The initial plants were built and brought onstream in a record time of nine months.

Firestone produced the program’s first bale of synthetic rubber on April 26, 1942, followed by Goodyear on May 18, United States Rubber on



Goodyear plant workers with WWII rubber assault craft.

September 4, and Goodrich on November 27. In 1942, these four plants produced 2,241 tons of synthetic rubber. By 1945, the United States was producing

about 920,000 tons per year of synthetic rubber, 85% of which was GR-S rubber. Of that 85%, the four major companies were producing 547,500 tons per year (70%).

Research continued after the war ended in August 1945. Synthetic rubber was improved and, after the wartime plants served again during the Korean Conflict, became an integral part of the rubber industry. GR-S production returned to private hands in 1955 when the government sold the plants. As the 20th century draws to a close, the rubber industry has grown to a \$60 billion international enterprise with about 15,000 establishments operating in the United States. Synthetic rubber is a vital part of the transportation, aerospace, energy, electronics, and consumer products industries.

FURTHER READING

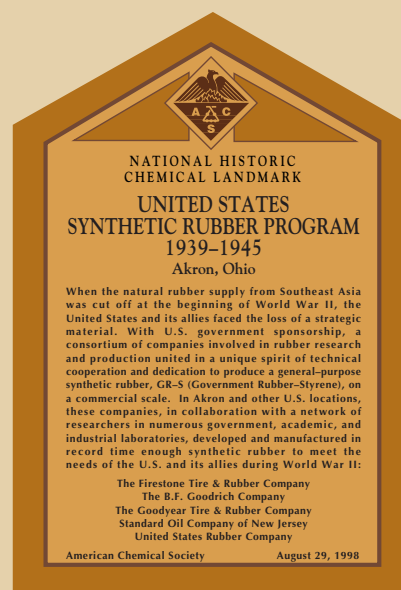
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THE NATIONAL HISTORIC CHEMICAL LANDMARKS PROGRAM OF THE AMERICAN CHEMICAL SOCIETY

The ACS National Historic Chemical Landmarks Program recognizes our scientific and technical heritage and encourages the preservation of historically important achievements and artifacts in chemistry, chemical engineering, and the chemical process industries. It provides an annotated roster to remind chemists, chemical engineers, students, educators, historians, and travelers of an inspiring heritage that illuminates where we have been and where we might go when traveling the diverse paths to discovery.

An ACS historic chemical landmark represents a distinctive step in the evolution of the chemical sciences and technologies. Designations of sites and artifacts note events or developments of clear historical importance to chemists and chemical engineers. Historic collections designations mark the contributions of a number of objects with special significance to the historical development of chemistry and chemical engineering.

The NHCLP began in 1992, when the Division of the History of Chemistry of the ACS formed an international Advisory Committee. The committee, composed of chemists, chemical engineers, and historians of science and technology, works with the ACS Office of Communications and is assisted by the Chemical Heritage Foundation. Together, these organizations provide a public service by examining, noting, recording, and acknowledging particularly significant achievements in chemistry and chemical engineering. For further information, please contact the ACS Office of Communications, 1155 Sixteenth Street, N.W., Washington, DC 20036; 800-ACS-5558, ext. 6274.



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