

A NATIONAL HISTORIC
CHEMICAL LANDMARK

DISCOVERY OF POLYPROPYLENE AND THE DEVELOPMENT OF A NEW HIGH-DENSITY POLYETHYLENE

PHILLIPS PETROLEUM COMPANY
BARTLESVILLE, OKLAHOMA
NOVEMBER 12, 1999



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



Robert L. Banks (L) and J. Paul Hogan receiving the Perkin Medal in 1987.

This booklet commemorates the designation of the discovery of polypropylene and the development of a new high-density polyethylene process as a National Historic Chemical Landmark. The designation was conferred by the American Chemical Society, a nonprofit scientific and educational society of more than 159,000 chemists and chemical engineers. A plaque marking the designation was presented to Phillips Petroleum

Company, Bartlesville, Oklahoma, on November 12, 1999.

The inscription reads:

“In 1951, while attempting to convert propylene into gasoline, J. Paul Hogan and Robert L. Banks of Phillips Petroleum Company discovered polypropylene, a high-melting crystalline aliphatic hydrocarbon. This discovery led to the development of a new catalytic process for the making of high-density polyethylene. Now, billions of pounds of polypropylene and high-density polyethylene are used each year in packaging of every shape and size, from milk jugs to large chemical drums; in toys, tools, furniture, and fibers; in water, sewer and gas pipes; and in auto parts. These polymers have become an integral part of our everyday lives.”

On the cover: The Phillips Hydrocarbon Research Laboratory, 1927.

Acknowledgments:

The American Chemical Society gratefully acknowledges the assistance of those who collaborated on the content of this booklet, including Kathleen B. Triebel, Bryan E. Hauger, Dale E. Parsons, Lyell H. Carver, and Katherine M. Powell, all of Phillips Petroleum Company, and Frankie K. Wood-Black, Phillips Petroleum Company, the NHCLP Advisory Committee liaison.

This booklet was produced by the American Chemical Society Office of Communications. Design: Dahlman Middour Design. Copyediting: Kelley B Carpenter, ACS. Photographs courtesy of Phillips Petroleum Company.

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PHILLIPS TURNS TO PLASTICS

Phillips Petroleum Company in Bartlesville, OK, entered the plastics business in 1951, following a discovery by researchers J. Paul Hogan and Robert L. Banks. The two researchers had been looking for ways to convert ethylene and propylene—hydrocarbons produced when refining natural gas—into components for gasoline. In the process, they found the catalyst that would transform these products into solid polymers. The plastics that resulted—crystalline polypropylene and high-density polyethylene—are now the core of a multibillion-dollar, global industry.

A History of Innovation



George Oberfell.

In 1951, polymer chemistry was still in its infancy. The key people at Phillips had little, if any, experience with plastics. But the company had a history of trying new ideas and supporting and funding their development.

In 1925, research director George Oberfell convinced founder Frank Phillips to investigate additional uses for natural gas liquids. Two

years later, Oberfell established one of the world's first hydrocarbon research laboratories, moving the company into new arenas in the production and marketing of fuels and of raw materials for the chemical industries. In

1935, he urged the company to acquire vast quantities of natural gas acreage and to pursue research on the separation of natural gas into its various components. So if Hogan and Banks's discovery was in fact serendipitous, it was not accidental: Phillips had set the stage for important innovations in the uses of natural gas.

It is hard to do justice to plastic because it serves so many functions, assumes so many guises, satisfies so many desires, and so quickly recedes into relative invisibility as long as it does its job well. In a little more than a century, plastics have spread throughout the material world, moving from almost no presence at all to near ubiquity.

Jeffrey L. Meikle,
American Plastic: A Cultural History



The Phillips Research Complex, Bartlesville. Inset shows the site of the development of polypropylene.

SCIENCE AND SERENDIPITY

In the late 1940s, as World War II ground to a halt and wartime demands for oil diminished, Phillips looked for ways to expand its product lines. With large quantities of natural gas on hand, Phillips chemists and engineers investigated ways to utilize propylene and ethylene, products of the refining process. Hogan and Banks were assigned to study the processes by which these gases could be converted into gasoline components.

In the course of these investigations, Hogan and Banks began to study catalysts and what makes them work. In June 1951, they set up an experiment in which they modified their original catalyst (nickel oxide) to include small amounts of chromium oxide. Ordinarily, the combination would be expected to produce low-molecular-weight hydrocarbons. They fed propylene, along with a propane carrier, into a pipe packed with catalyst and waited for the expected results.

As Paul Hogan recalls it, he was standing outside the laboratory when Banks came out saying, "Hey, we've got something new coming in our kettle that we've never seen before." Running inside, they saw that the nickel oxide had produced the expected liquids. But the chromium had produced a white, solid material. Hogan and Banks were looking at a new polymer—crystalline polypropylene. Hogan said his reaction was immediate: He sat down at his desk and wrote up a patent idea, and he and Banks both signed it.

With full support from Phillips management, Hogan and Banks quickly switched their research efforts from gasoline production to the development of plastics.



Robert L. Banks; research supervisors Alfred Clark and Clarence Lanning; J. Paul Hogan. Under the supervision of Clark and Lanning, Banks and Hogan were given the freedom to divert their research from gasoline additives to plastics.

Their first step was to omit the nickel to be sure the chromium was acting alone. The next was to use their new chromium catalyst to produce an ethylene polymer. Though polyethylene had been invented in the 1930s (by the British company Imperial Chemical Industries), the production process required extreme pressures of 20 to 30 thousand pounds per square inch (psi), and it produced a branched, low-density polymer. In less than a year, Hogan and Banks developed a new process that required only a few hundred psi—and produced a high-density polyethylene (HDPE) far stiffer, harder, and more heat-resistant than anything on the market. This new discovery launched Phillips into an entirely new industry: the manufacture of a family of polyolefin plastics that included both the polypropylenes and polyethylenes.

Phillips management nurtured the new plastics from laboratory discovery to commercial-scale production in less than six years—no mean feat for an oil company new to the plastics industry!

Today, chromium catalysts still account for most of the world's HDPE. Hundreds of different grades of resin are produced globally by a variety of manufacturing processes from scores of different variants on the original chromium catalyst.

A lot of empiricism and some serendipity is needed for success in the field of industrial catalysis . . . serendipity in science ripens into fruition only when the unexpected phenomenon is observed by a scientist with a large bump of curiosity

P. M. Arnold, Vice President, Phillips R&D.
The Chemist, April 1971.

Polypropylene

AUTOMOTIVE Battery cases and trays Bumpers Fender liners Interior trim Reservoirs **EDUCATION**

HOME Appliance housings Food packaging Microwave cookware Bottles and containers **INDUSTRY** Carpeting Crates and pallets

RECREATION Safety equipment Ski rope Sporting goods Sportswear

HDPE

AUTOMOTIVE Fuel tanks Motor oil containers Portable gas cans Under-hood reservoirs Wire insulation **EDUCATION**

HOME Food and drink containers Household product bottles Outdoor furniture Toys Trash

MEDICAL Biomedical waste containers Pharmaceutical bottles Tubing and catheters **MUNICIPAL** Highway barriers Slip-resistant

ON THE MARKET

Phillips introduced HDPE in 1954, under the brand name Marlex® polyethylene. Company marketing executives were wildly optimistic. Recalling this early time, project manager R. G. Rhodes said he thought that [the material was] so good we wouldn't have to sell it . . . The customers would come and take it away from us. But the market had become large and diverse and Marlex®, then produced in only one grade, was unsuitable for some applications. Inventories piled up in the warehouses.

The turnaround came from an unlikely source—a large ring of plastic tubing called the hula hoop. This children's toy became so immensely popular that the demand for Marlex® soared, taking the plant's entire output for nearly six months. Phillips president Paul Endacott was so delighted that he kept a hoop in his office for impromptu demonstrations. The toy's popularity continued long enough for Phillips to improve the production process and expand the number of available product grades.

The hula hoop craze helped pave the way for more practical uses, such as commercial and industrial tubing. In time, Marlex® also became the preferred plastic for baby bottles (because of its ability to withstand the high temperatures of sterilization) and for safe, shatterproof containers for food and other household products.

In the Courts

Paul Hogan and Robert Banks signed the patent idea describing the process by which they produced crystalline polypropylene about an hour after their discovery. The patent was issued 32 years later.

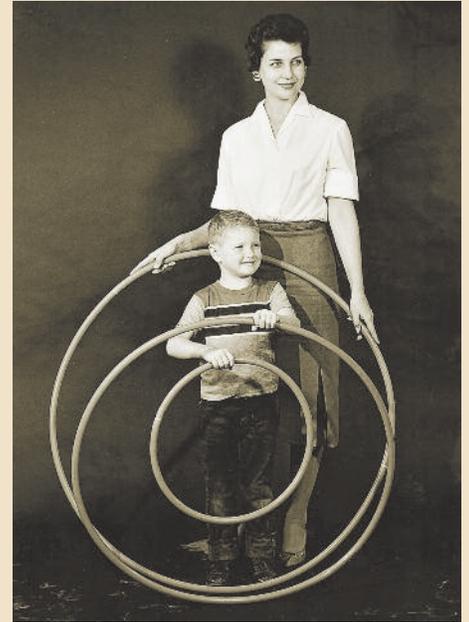
Remarkably, the catalytic polymerization of propylene at low pressure to polypropylene (with three different catalytic systems) was discovered within a brief period by researchers in three separate laboratories, none knowing that the others were even pursuing the problem.

Between 1951 and 1953, three patent applications on the discovery of polypropylene were filed—by Hogan and Banks; A. Zletz of Standard Oil; and

Karl Ziegler of the Max Planck Institute. In 1958, the U.S. Patent Office declared an interference, a proceeding in which it heard evidence regarding the claims of these and two additional companies.

Patent Office actions and the court battle that followed lasted three decades and produced volumes of testimony and scientific research. Indeed, the court's decision contained what may be the most complete scientific record of a crystalline material.

It was believed for many years that Prof. Ziegler and Italian scientist Giulio Natta were responsible for the discovery, because they had been the first to publish their findings—and because they had received the Nobel Prize for their work on these polymers. In 1983, an appellate court ruled that the patent did indeed belong to J. Paul Hogan, Robert L. Banks, and the Phillips Petroleum Company.



Fans pose with their hula hoops.

Market Impact

The discovery of crystalline polypropylene and the development of HDPE launched what is now a multibillion-dollar industry. The list below gives only the smallest idea of the impact of these plastics, which are used in thousands of applications. Polypropylene and HDPE play a role in the management of serious environmental issues. They are used in medical care and in public health and are essential materials in a variety of manufacturing industries and consumer-product companies. Importantly, these plastics also have created industries that provide thousands of jobs and business opportunities in this country and around the world.

CAUTION Binders Transparent sleeves Writing instruments **ENVIRONMENT** Geotextiles for erosion Pavement underliners
and trays Filters Office furniture Tapes Woven bags **MEDICAL** Food service ware Medical ware Packaging Syringes **MUNICIPAL** Ropes and twine

CONSTRUCTION Classroom and stadium seating Notebook binders **ENVIRONMENT** Chemical toilets Erosion barriers Landfill liners Pond and canal liners
and lawn bags **INDUSTRY** Cable jacketing Oil and gas lines Packaging films Tanks and drums Wire insulation
lining for sewers Trash containers Utilities pipe **RECREATION** Basketball backboards Food and water coolers Ski equipment Watercraft components

J. PAUL HOGAN AND ROBERT L. BANKS



Robert Banks.



Paul Hogan.

Considering their similar backgrounds, it seems fitting that Paul Hogan and Robert Banks would eventually come together as a team. The two grew up in small towns barely 100 miles apart. Hogan was born in 1919 and spent his childhood in southwestern Kentucky, near the small town of Lowes. Banks was born two years later, in 1921, and grew up in the southeastern Missouri community of Piedmont. Both of their mothers were teachers. Banks's mother, Maude, was a music teacher before she married. Hogan's mother, Alma, taught elementary school. Banks's father, James, was a dentist in Piedmont. Hogan's father, Charles, was well known in Lowes as a farmer, mechanic, and proprietor of a local store.

Banks received a B.S. degree from the University of Missouri-Rolla and an M.S. degree in chemical engineering from Oklahoma State University. Hogan received a B.S. degree in chemistry and physics from Murray State University, in Murray, KY, in 1942. During World War II, Banks worked as a process engineer at an aviation gasoline plant in Coffeyville, KS, and Hogan became an instructor at an Army preflight school in Oklahoma.

After the war ended, both men joined Phillips as research chemists—Hogan in 1944 and Banks in 1946. In 1949, they began their now famous collaboration.

After their discovery of polypropylene and the development of HDPE, the two men continued to make important contributions. Banks went on to discover olefin metathesis, a key factor in the growth of the synthetic chemical business. Hogan continued to develop the chromium catalyst for ethylene polymerization and led a research team dedicated to exploring chromium catalysts. Both men climbed the Phillips ladder, achieving the level of senior research associate. Hogan and Banks retired in the same year, 1985. Two years later, they received the Society of Chemical Industry's Perkin Medal for their contributions to chemistry. In 1998, the American Chemical Society gave Banks (posthumously) and Hogan a "Heroes of Chemistry" award for the use of petrochemicals in the automotive industries.

Robert Banks died in 1989. Paul Hogan lives in Bartlesville, where he is active as a deacon in the Baptist Church.

FURTHER READING

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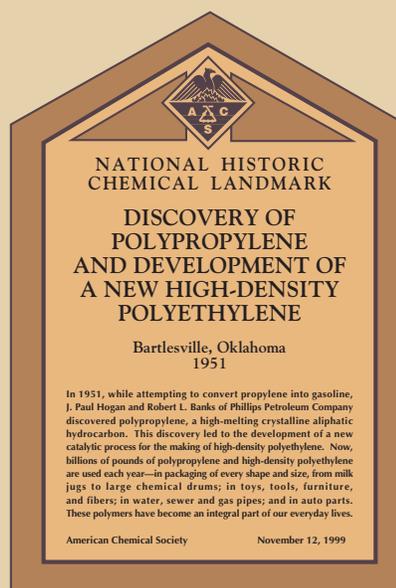
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The ACS National Historic Chemical Landmarks Program recognizes our scientific and technical heritage and encourages the preservation of historically important achievements and artifacts in chemistry, chemical engineering, and the chemical process 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. Collections mark the contributions of a number of objects with special significance to the historical development of chemistry and chemical engineering.

This program 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, NW, Washington, DC 20036; telephone: 800-227-5558, ext. 6274; e-mail: nhclp@acs.org.



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American Chemical Society
1155 Sixteenth Street, N.W.
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