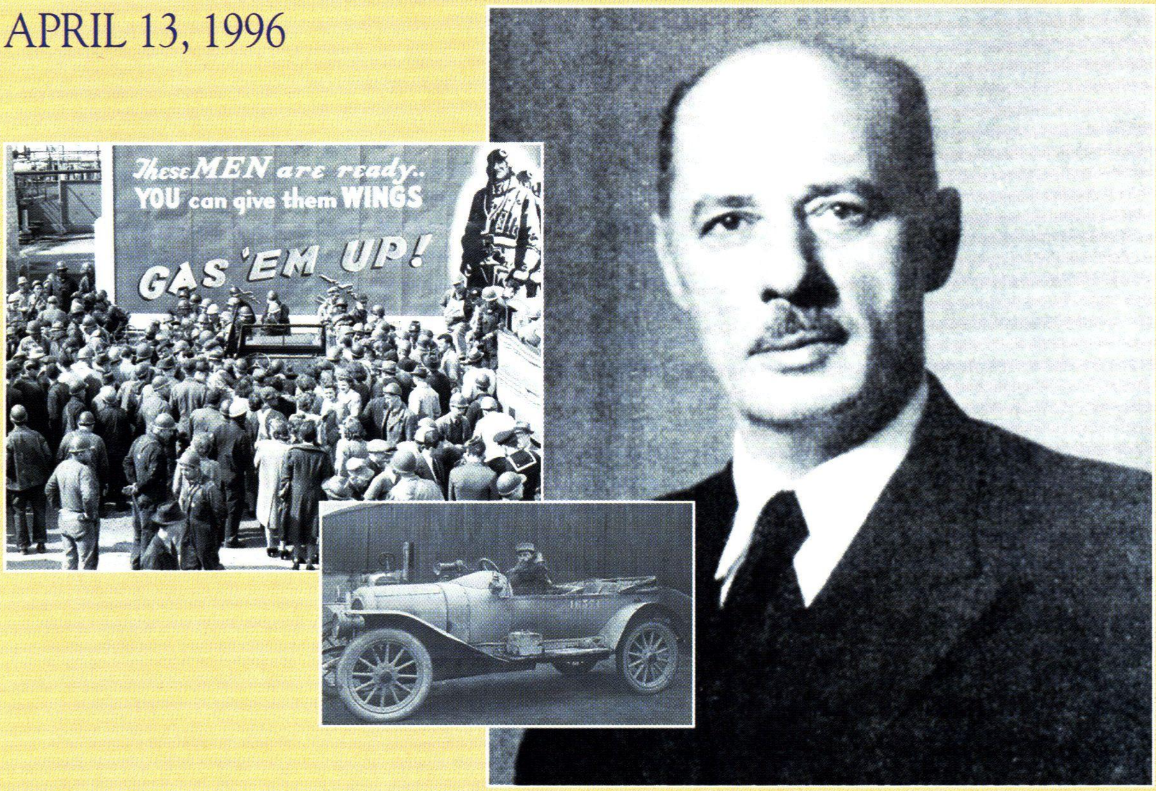
A NATIONAL HISTORIC
CHEMICAL LANDMARK

THE HOUDRY PROCESS

FOR THE CATALYTIC CONVERSION OF CRUDE PETROLEUM TO HIGH-OCTANE GASOLINE

SUN COMPANY
MARCUS HOOK, PENNSYLVANIA

APRIL 13, 1996



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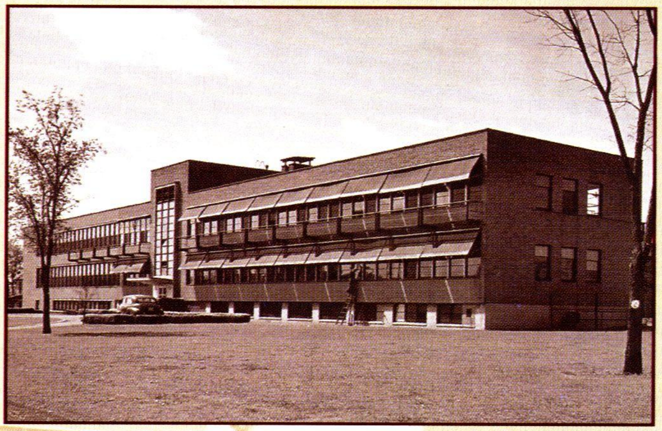

The Houdry Process Corporation laboratory in Linwood, Pa.

This booklet commemorates the designation of The Houdry Process for the Catalytic Conversion of Crude Petroleum to High-Octane Gasoline as a National Historic Chemical Landmark. The designation was conferred by the American Chemical Society, a nonprofit scientific and educational organization of 150,000 chemists and chemical engineers.

ACS plaques marking the designation were presented to the Sun Company on April 13, 1996, for installation at the Marcus Hook Refinery and the Houdry Laboratories site in Linwood, Pennsylvania. The inscriptions read: "The first full-scale commercial catalytic cracker for the selective conversion of crude petroleum to gasoline went on stream at the Marcus Hook Refinery. Pioneered by Eugene Jules Houdry (1892-1962), the catalytic cracking of petroleum revolutionized the industry. The Houdry process conserved natural oil by doubling the amount of gasoline produced by other processes. It also greatly improved the gasoline octane rating, making possible today's efficient, high-compression automobile engines. During World War II, the high-octane fuel shipped from Houdry plants played a critical role in the Allied victory. The Houdry laboratories in Linwood became the research and development center for this and subsequent Houdry inventions."

Acknowledgments:
The American Chemical Society gratefully acknowledges the assistance of the scientists and historians who helped us to prepare this booklet, including: G. Alex Mills, ACS Division of Fuel Chemistry; James E. McEvoy, ACS Division of Industrial and Engineering Chemistry; and James J. Bohning of the American Chemical Society, the NHCLP Advisory Committee liaison.

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Background: The catalytic cracking unit at Marcus Hook, Pa., 1938.

TRANSFORMING CRUDE OIL INTO GASOLINE

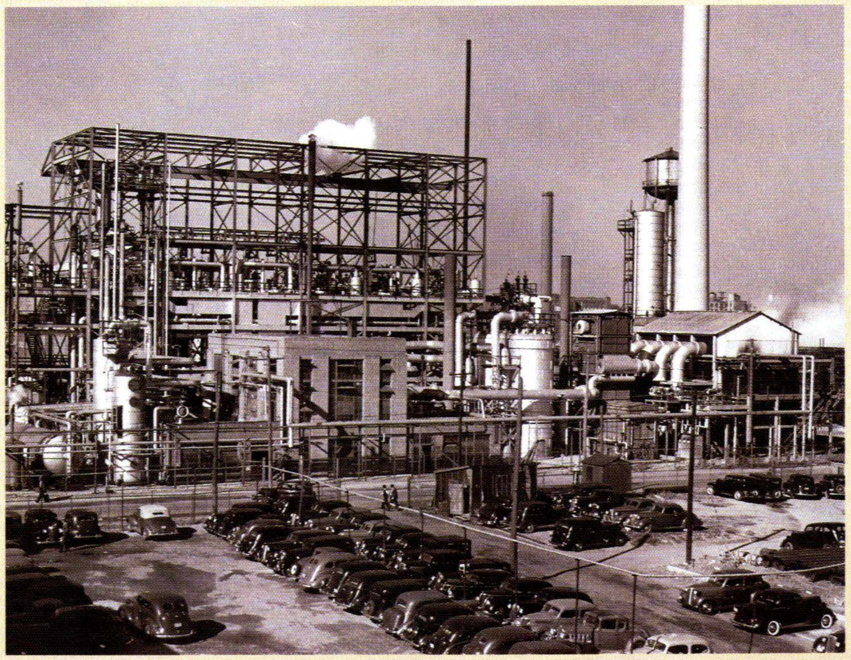
Commercial production of petroleum began in Titusville, Pennsylvania, in 1859. The internal combustion engine was developed soon after, and the first gasoline-fueled "horseless carriages" appeared on American streets in 1895. But since only wealthy people could afford them, there were probably no more than 8000 automobiles in the United States by the turn of the century.

Crude petroleum is a complex mixture of hydrocarbon molecules, compounds containing carbon and hydrogen atoms. Initially, crude petroleum was separated by distillation into fractions distinguished by differences in their boiling points. Some higher-boiling fractions were used for lighting and some for lubrication, but for many years, little use was found for the gasoline component.

As the number of automobiles, trucks, and tractors increased, the demand for gasoline increased, and by 1910—when there were 500,000 automobiles—a gasoline shortage had developed. It occurred to a few perceptive inventors that it might be possible to produce additional gasoline from the unused, higher-boiling petroleum fractions. In 1913, Dr. William Burton of Standard Oil of Indiana introduced a thermal-cracking procedure that used high temperature and pressure to break down the larger, higher-boiling molecules into the smaller, lower-boiling molecules found in gasoline.

It was recognized that more efficient engine performance could be achieved from a fuel that had a higher "octane rating," the measure of a fuel's efficiency in a standard engine. The first significant increase in octane rating was obtained in 1923, when Standard Oil of Indiana, using a discovery of Thomas Midgley, Jr., of General Motors, added tetraethyl lead to gasoline.

In the early 1920s, the French engineer Eugene Jules Houdry began his search for a catalyst to produce gasoline from lignite. A catalyst is a substance that can increase the rate at which a chemical reaction occurs, without itself being changed. Because it has the potential to produce very selective results, such as the cracking of high-boiling petroleum fractions to gasoline, a catalyst can give a particular process a competitive advantage. In the 1920s, the science of catalysis was still in its infancy, and the business applications were limited to the hydrogenation of vegetable oils to make butter substitutes, the conversion of atmospheric nitrogen to make ammonia for fertilizers and explosives, and the conversion of carbon monoxide to make methanol or hydrocarbons. The Gulf Oil Corporation had tried to replace the energy-intensive thermal cracking of the higher-boiling petroleum fractions with an aluminum chloride catalyst, but the results were not economically successful because the cost was too high.



The catalytic cracking unit at Marcus Hook, 1938

THE HOUDRY PROCESS

As an avid participant in the sport of automobile racing, Eugene Houdry was acutely aware of the importance of high-performance fuels for successful machine performance. As a Frenchman, Houdry was also aware of the growing need for gasoline in a country that was deficient in its own petroleum resources.

In 1922, Houdry learned about an exceptional gasoline derived from lignite that was being produced in a catalytic procedure by E. A. Prudhomme, a pharmacist in Nice, France. Houdry visited Prudhomme and persuaded him to move to Beauchamp, near Paris, where Houdry and some of his business associates financed and set up a laboratory. For the next few years, Houdry worked closely with Prudhomme and others to develop a workable lignite-to-gasoline process.

Supported by the French government, Houdry's syndicate built a demonstration plant that processed 60 tons of lignite per day to produce oil and gasoline. The plant started operations in June 1929, but the results were disappointing and the process was not economically competitive. The government subsidy was withdrawn, and the plant was shut down in that same year.

During the lignite-to-gasoline process, the solid lignite was initially broken down by heat to produce viscous hydrocarbon oil and tars—then the oil was further converted by an added catalyst to produce lower-boiling hydrocarbons similar to the gasoline fraction derived from petroleum. Although much emphasis had been placed by others on nickel-containing catalysts, Houdry discovered that a clay mineral named Fuller's Earth, a naturally occurring aluminosilicate, could convert the oil derived from lignite to a gasoline-like product. Working with this knowledge, Houdry focused his attention on the application of catalysis to petroleum processing.

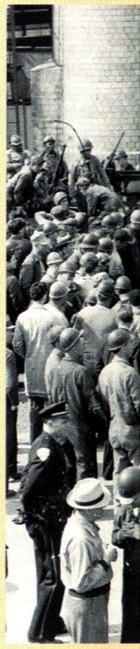
In 1930, H. F. Sheets of the Vacuum Oil Company learned of Houdry's promising results using a catalyst to convert vaporized petroleum to gasoline, and invited him to come to the United States. After a successful trial run, Houdry moved his laboratory and associates from France to Paulsboro, New Jersey.

The Houdry Process Corporation was founded in 1931, a joint venture of Houdry with his associates at the Vacuum Oil Company. That same year, Vacuum Oil merged with Standard Oil of New York to form the Socony-Vacuum Oil Company (later Mobil Oil Corporation). In 1933, a 200-barrel-per-day Houdry unit was put in operation. But the Great Depression had weakened the oil business. Unable to finance Houdry's work any further, Socony-Vaccuum gave him permission to seek support from other petroleum companies.

Arthur Pew, Jr., in 1938.

In late 1933, Houdry met with Sun Oil Company (later Sun Company) president J. Howard Pew and vice president for refining Arthur Pew, Jr. Shortly thereafter, Houdry, Socony-Vacuum, and Sun signed a joint development agreement. In the next few years, the Houdry process underwent further changes, including an innovative method for regenerating the catalyst after a short, ten-minute usage time.

These results inspired Socony-Vacuum and Sun to proceed to commercialization. In April 1936, Socony-Vacuum converted an older thermal-cracking unit in Paulsboro into a semi-works unit using the Houdry process. In March 1937, Sun's new, fully commercial unit went into operation. Processing 15,000 barrels of petroleum per day, this unit featured such innovations as a molten-salt heat control technique and motor-operated valves controlled by timers. Almost 50 percent of the product was high-octane gasoline, compared with 25 percent from the more conventional thermal processes.

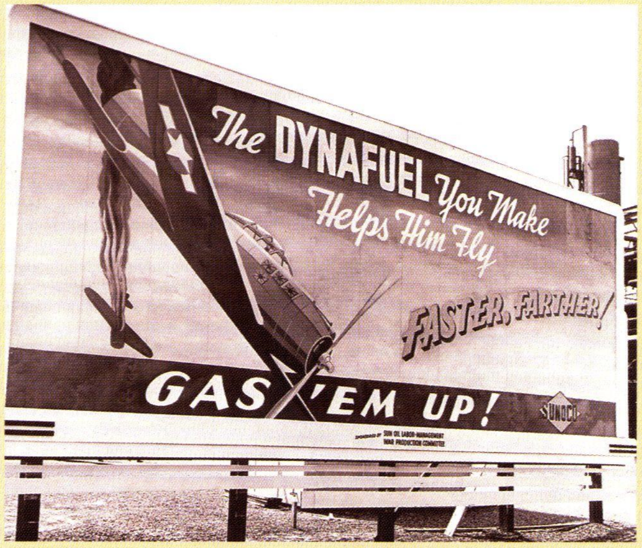


When Arthur Pew, Jr., presented the details of the successful commercial process at a 1938 meeting of the American Petroleum Institute, the industry was astounded. An article in *Fortune* magazine, entitled "Monsieur Houdry's Invention," said Pew "had dropped a bombshell." In 1940, the first large-scale plant for producing a synthetic silica-alumina catalyst began operations in Paulsboro.

IMPACT OF THE HOUDRY INVENTION

The invention and development of gasoline-fueled motor vehicles has had a profound influence on human history—providing transport for industrial products and employment for millions and determining where and how we live, work, and play. In the United States today, more than half of the 300 million gallons of gasoline used each day to fuel more than 150 million passenger cars is produced by catalytic-cracking technology. High-octane gasoline paved the way to high compression-ratio engines, higher engine performance, and greater fuel economy.

The most dramatic benefit of the earliest Houdry units was in the production of 100-octane aviation gasoline, just before the outbreak of World War II. The Houdry plants provided a better gasoline for blending with scarce high-octane components, as well as by-products that could be converted by other processes to make more high-octane fractions. The increased performance meant that Allied planes were better than Axis planes by a factor of 15 percent to 30 percent in engine power for take-off and climbing; 25 percent in payload; 10 percent in maximum speed, and 12 percent in operational altitude. In the first six months of 1940, at the time of the Battle of Britain, 1.1 million barrels per month of 100-octane aviation gasoline was shipped to the Allies. Houdry plants produced 90 percent of this catalytically cracked gasoline during the first two years of the war.



World War II billboard at the Marcus Hook Refinery.

The original Houdry process embodied several innovative chemical and engineering concepts that have had far-reaching consequences. For example, the improvement of the octane rating with catalytic processes showed that the chemical composition of fuels was limiting engine performance. Further, aluminosilicate catalysts were shown to be efficient in improving the octane rating because they generated more highly branched isoparaffins and aromatic hydrocarbons, which are responsible for high octane ratings. From an economic standpoint, the catalysts could be regenerated after a short usage time, thus returning the catalyst to full activity without having to add additional material.

The original fixed-bed Houdry Process units have been outmoded by engineering advances that transformed the fixed-bed to more economical fluidized-bed systems and introduced the use of crystalline aluminosilicate catalysts to provide higher yields of gasoline. Yet it is remarkable that, seventy years after Houdry's discovery of the catalytic properties of activated clay to convert petroleum fractions to gasoline, the same fundamental principles that made the process a success are still the primary basis for manufacturing gasoline worldwide.

Sun Oil employees at a wartime rally.

EUGENE JULES HOUDRY


Eugene Houdry in 1960.

Born near Paris, France, on April 18, 1892, Eugene Jules Houdry was the son of a wealthy steel manufacturer. He studied mechanical engineering at the Ecole des Arts et Métiers in Chalons-sur-Marne, a Paris suburb. He graduated in 1911, earning the French government's gold medal for the highest scholastic achievement in his class. He was captain of his school's soccer team, which won the championship of France that same year.

Houdry joined his father's business, but left for military training, where he was at the outbreak of World War I. He served in the French army as a lieutenant in the tank corps and in 1917 was seriously wounded in the battle of Juvincourt, winning the Croix de Guerre for his actions and later becoming a Chevalier of the Legion of Honor.

After the war, Houdry rejoined his father at Houdry et Fils, but by 1922 was making his way in the field of catalytic processes for the conversion of coal and lignite to gasoline. His interest in high-octane gasoline was fueled by his avid interest in automobile engines and in road racing, where he competed in a Bugatti racing car.

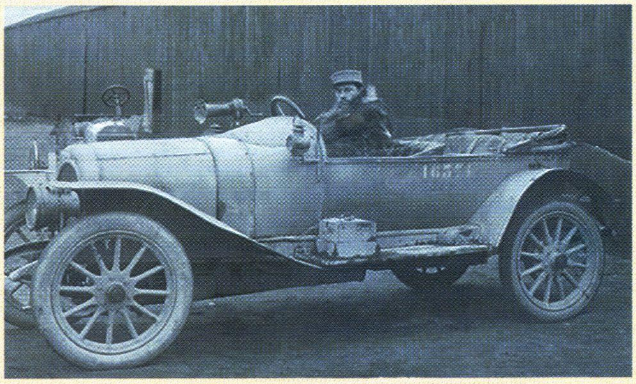
In addition to the process for high-octane gasoline, Houdry also invented a catalytic process for the production of butadiene from the butane gas derived from crude oil production. Butadiene became an important resource during World War II. It was one of the two components used in the synthetic rubber program initiated after natural rubber supplies were eliminated by the war in the Pacific.

Houdry was outspoken in his opposition to wartime collaboration with the Germans by the French Vichy government of Marshall Henri Pétain. On May 3, 1941, the Vichy government declared that Houdry had lost his French citizenship. He then became president of the U.S. chapter of "France Forever"— an organization dedicated to the support of General Charles de Gaulle, the nominal head of the French government in exile—and in January 1942, he became a United States citizen. His two sons, Jacques and Pierre, served in the United States Army during World War II, and Houdry directed his efforts towards industrial processes crucial to the war effort.

After World War II, Houdry formed the Oxy-Catalyst Company and turned his attention to reducing the health risks associated with the increasing amounts of automobile and industrial air pollution. His generic catalytic converter, which greatly reduced the amount of carbon monoxide and unburned hydrocarbons in automobile exhausts, was granted U.S. Patent 2,742,437 in 1956. Today, catalytic converters made by various companies are standard devices on all American cars.

Houdry's colorful life was full of great ambitions. His unusually productive career was characterized by unique foresight, bold imagination, creative leadership, persistence and, above all, action. Houdry's contributions to catalytic technology were recognized by numerous awards, including the Potts Medal of the Franklin Institute in 1948, the Perkin Medal of the Society of Chemical Industry (American Section) in 1948, the E. V. Murphree Award in Industrial and Engineering Chemistry of the American Chemical Society in 1962, and posthumous election to the National Inventors Hall of Fame in 1990. He was awarded honorary Doctor of Science degrees by Pennsylvania Military College in 1940 and by Grove City College in 1943. In 1967, the Catalysis Society of North America established the Houdry Award in Applied Catalysis.

Houdry died on July 18, 1962, at the age of 70, survived by his sons and his wife, Genevieve Quilleret. At that time he was actively working on creative ideas for using catalytic processes to improve human health.


Eugene Houdry as a lieutenant in the tank corps of the French army during World War I.

SUGGESTED READING

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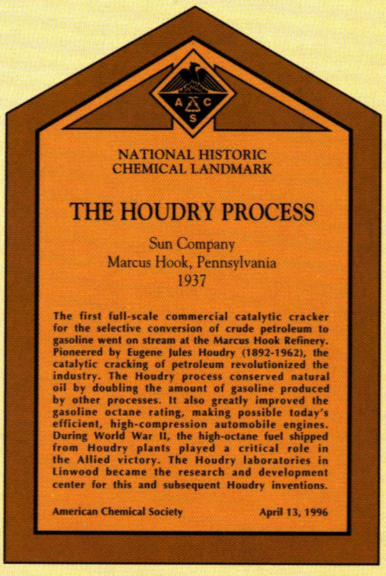
THE NATIONAL HISTORIC CHEMICAL LANDMARKS PROGRAM OF THE AMERICAN CHEMICAL SOCIETY



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 both where we have been and where we might go when traveling the diverse paths to discovery.

ACS Historic Chemical Landmarks represent or are closely linked to seminal achievements in the chemical sciences and technologies. A site designation marks the location of an artifact, event, or other development of clear historical importance to chemists and chemical engineers. An historic collection designation marks 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 Public Outreach 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 Public Outreach, 1155 Sixteenth Street, N.W., Washington, D.C. 20036; 1-800-227-5558, Ext. 6293.

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