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# Burton Introduces Thermal Cracking for Refining Petroleum

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## BURTON INTRODUCES THERMAL CRACKING FOR REFINING PETROLEUM

*Category of event:* Chemistry

*Time:* January, 1913

*Locale:* Whiting, Indiana

*Employing high temperatures and pressures, Burton developed a large-scale chemical cracking process, thus pioneering a method that met the need for more fuel*

### *Principal personages:*

WILLIAM MERRIAM BURTON (1865-1954), a chemist who developed a commercial method to convert high boiling petroleum fractions to gasoline by "cracking" large organic molecules into more useful and marketable smaller units

ROBERT E. HUMPHREYS, a chemist who collaborated with Burton

WILLIAM F. RODGERS, a chemist who collaborated with Burton

EUGENE HOUDRY, an industrial scientist who developed a procedure using catalysts to speed the conversion process, which resulted in high-octane gasoline

### **Summary of Event**

In January, 1913, William Merriam Burton saw the first battery of twelve stills used in the thermal cracking of petroleum products go into operation at Standard Oil of Indiana's Whiting refinery. Although the process would be quickly modified and more efficient techniques and apparatus would be employed by the early 1920's, the Burton process started a multifaceted revolution within the American petroleum industry not only in terms of products made but also in the sense that university-trained scientists were now recognized as possessing an expertise that could lead to enhanced corporate profits.

Although several individuals played important roles in the development of the Burton process, Burton was instrumental to its success. The scale up and commercialization of the process was the result of his vision, his ability to sense future changes in the market, his persistence in the laboratory, his technical skills, and his forceful determination in convincing skeptical Standard Oil of Indiana executives of the method's merit.

Burton earned a B.A. degree from Western Reserve University in 1886 and then attended The Johns Hopkins University, where he studied organic chemistry under Ira Remsen. After receiving his Ph.D. in 1889, Burton was hired by Standard Oil in Cleveland, and a year later transferred to the Whiting, Indiana, refinery where he set up a two-room laboratory in an old farmhouse overlooking Lake Michigan. Initially, Burton developed methods and fabricated apparatus that physically and chemically tested the refinery's kerosenes, greases, waxes, and lubricating oils; later, he used his chemical knowledge to eliminate unwanted sulfur compounds. In 1896, Burton

was promoted to refinery superintendent and other Hopkins-trained chemists took his place in the laboratory. One such scientist was Robert E. Humphreys, who subsequently proved to be a valuable collaborator with Burton in the development of the Burton process. At first, however, Burton and Humphreys would team up to tackle a number of small-scale, yet significant, practical problems that involved research on various kinds of greases and on the conversion of hydroxyteric acid from oleic acid, a product that was used to stiffen candles.

Burton began thinking about a feasible way in which more lighter petroleum materials could be obtained from existing stocks. Clearly, Burton had perceived the vicissitudes of a dynamic marketplace, one that was undergoing a dramatic transformation in the wake of the introduction of the automobile. Less kerosene and more gasoline was needed, and as Burton recognized, Standard Oil of Indiana's position at the beginning of the twentieth century was particularly vulnerable since Midwest oil field production was declining. His process not only would change the refinery product mix, increasing lighter organics and decreasing heavier oils, but also conserve existing stocks by greatly increasing the yield of petroleum's most sought after fraction, gasoline. Burton's idea of converting heavier fractions of petroleum to lighter ones was not new; indeed, by 1910 a number of petroleum refiners were operating the so-called coking process, in which heavy oils were placed in an open still and heated at atmospheric pressure, thereby causing the decomposition of some of these materials into a mixture of products that included kerosene and gasoline. Unfortunately, this process was highly inefficient, as little gasoline was made and considerable quantities of heavy coke lined the bottom of the vessels, insulating their walls.

Beginning in 1909, Burton—along with chemists Humphreys and William F. Rodgers—began investigations using a heated tube and lead bath that were aimed at examining the influence of temperature and reaction time on the cracking of various stocks or petroleum cuts into gasoline. While the yields of gasoline reached 20 percent and more, the scientists realized that the key to success was in keeping the heavy, higher molecular weight gas oil fraction from escaping the still before it could be properly cracked. Furthermore, the gasoline that was produced by this method was of poor quality and plugged fuel lines. To prevent this premature escape during distillation, several process techniques were evaluated, including the use of catalysts and the application of high pressures. While a few catalysts were haphazardly tried in the laboratory, the science of using inert materials to alter the course of a chemical reaction was in its infancy. Thus, Burton and his coinvestigators began to think of using high pressures to alter the reaction, yet this method, like catalysis, was an equally imposing technical challenge at this time.

Unknown to Burton, English chemists James Dewar and Boverton Redwood had demonstrated in 1899 that yields of gasoline increased markedly when heavy petroleum oils were heated under pressure, although Burton and his colleagues intuitively sensed that this result would happen. Using pint-sized "bombs" made of hollowed-out metal, Burton and Humphreys gradually raised the pressure in the small-scale

reaction vessels at 2.3 kilograms per square centimeter intervals to 34 kilograms; it was at this pressure—one that was dangerously approaching the limits of safety—that gas oil remained in the still and thus could be cracked into useful compounds of lower molecular weight like gasoline.

Major improvements in reactor design quickly followed this discovery. Humphreys added a long inclined tube to the original arrangement of the apparatus, connecting this so-called run-back between the still and the condensing apparatus and thus separating vaporized kerosene from gasoline. With this innovation, yields and product quality were enhanced, and Burton was now in a position to sell his new process to Standard Oil's management. After more than a year of delays—in part the consequence of managerial resistance and in part the result of Standard Oil's legal difficulties related to antitrust difficulties—a pilot plant was erected. In 1912, construction began on the fabrication of the first set of sixty Burton stills, 9 meters in length and 2.4 meters in diameter, the size of the equipment determined by the largest sheets of steel then available.

Although operational difficulties ensued, refinery workers soon learned proper reaction parameters and equipment limitations. By the end of 1913, 240 stills were in place, and profits soared. For each barrel of gas oil distilled and cracked, the company earned twenty-five cents, and further expansion followed. In 1915, Standard Oil (Indiana) sold more than 2.5 million 189-liter barrels of gasoline made in Burton stills, and five years later output rose to more than 5.8 million barrels.

At first, the company had difficulty in marketing the new product, as it passed a yellow hue and had an offensive odor because of the presence of by-product sulfur compounds. The physical properties of this so-called Motor Spirit were dramatically improved, however, by treating the material with sulfuric acid, and it was later blended with "straight run" gasoline.

As the product's quality was enhanced, the Burton process was modified between 1913 and 1920 in several minor yet important respects. In 1914, false bottom plates were installed in the stills; this minor design alteration increased the vessel's capacity as well as efficiency. The introduction of an air-cooled radiator in 1915 and bubble towers in 1918 led to better fractionation and more and better grades of gasoline.

In short, the Burton process transformed the fortunes of Standard Oil (Indiana) and indeed the entire petroleum industry. Although it was licensed for use in many areas of the world—including Indonesia and Romania—its long-term significance was that it would initiate a wave of technical change in a rather conservative industry, causing tradition-bound methods to be supplanted by science-based techniques. Indeed, a wholly new petroleum industry emerged within two decades of Burton's innovation.

### **Impact of Event**

The Burton process influenced the course of the future petroleum industry both directly and indirectly. As a result of Burton's innovation, the amount of gasoline

marketed not only by Standard Oil (Indiana) but also by its competitors increased sharply in the decades immediately after its introduction. Thus, in 1925 more than 23 million barrels of gasoline were produced in Burton stills alone. In addition, the severe demands placed on the apparatus by the high temperatures and pressure employed in the process resulted in the development of new reaction vessels, valves, and fittings that were designed to withstand these extreme conditions, and these improvements were utilized in industrial settings outside the petroleum industry. Furthermore, the work of Burton, Humphreys, and Rodgers demonstrated convincingly the value of scientific and technical expertise within the corporate environment. Within a decade of the adoption of the Burton process, most chemical plants and refineries were under the control of scientists rather than foremen; science-based industry was now a reality.

Although engineers continued to improve the Burton process during the decade following its introduction, its long-term significance lay in its pioneering the technological foundations of what emerged as the rapidly emerging field of petroleum cracking technology. The Burton process was a batch process, but by the 1920's continuous thermal cracking processes were developed. Jesse A. Dubbs and his son Carbon P. Dubbs made the most significant early contributions in this field, and their inventions formed the basis of the Universal Oil Products Company. In 1915, Jesse Dubbs patented a process for an apparatus that broke up stubborn water-oil emulsions, and his son incorporated these ideas on continuous flow with the concept of "clean circulation," in which cracked materials from medium weight fractions were separated from heavy portions by subdividing the steams flowing from the cracking coils. Nevertheless, the Dubbs process had inherent inefficiencies, and these shortcomings could be overcome only by using catalysts. It remained for a French industrial scientist, working with American chemists and chemical engineers, to develop an alternative. As a result of his interest in racecar driving, Eugene Houdry searched for a catalyst that would promote the cracking process and result in an increased yield of high-octane gasoline. In 1931, Houdry came to the United States and formed the Houdry Process Company. Collaborating with chemists and engineers at the Sun Oil Company, Houdry developed a catalytic cracking process using cylindrical horizontally arranged reaction chambers and fast-acting valves to increase yields and quality. Compared to 72 octane gasoline produced by the Burton process, Houdry-process gasoline was 88 octane; it proved vital to the manufacture of high octane aviation gasoline during the early years of World War II. Yet, Houdry's design had several shortcomings, including its expensive apparatus and an inability to process heavy fractions and high-sulfur stocks.

As early as the mid-1930's, chemists and engineers sought to overcome these difficulties by designing a moving-bed method in which cracking of crude oil and regeneration of the catalyst took place simultaneously but in separate vessels. In 1938, Warren K. Lewis and E. R. Gilliland of MIT's Chemical Engineering Department combined the moving-bed design concept with the idea of a finely divided "fluid" catalyst, and the fluid cracking process was first put on stream in 1942. It

consisted of a regenerator and a reactor contained within a steel skeleton. Oil vapors were cracked in the reactor, where the reaction was accelerated by the fluidized catalyst and the product was separated in fractionating towers. The spent catalyst first flowed to a hopper and was then sent to the regenerator, where carbon was burned off the catalyst particles. The new manufacturing method was integral to the new petrochemical industry that emerged after World War II and that has created the modern synthetic world of the late twentieth century.

In a very real way, however, this modern synthetic world has its technological legacy in the work of Burton, whose process was perhaps the first in which petroleum was chemically transformed into more useful substances. He applied his scientific understanding to a problem in large-scale chemical manufacturing by harnessing knowledge about the fundamental structural properties of organic molecules and initiated a revolution in synthetic materials that continues to this day.

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- Giddens, Paul H. *Standard Oil Company (Indiana): Oil Pioneer of the Middle West*. New York: Appleton-Century-Crofts, 1955. In this definitive history of Standard Oil of Indiana, Giddens describes capably the origins of the Burton process and its economic impact upon the firm. Furthermore, the author traces the complex litigation that followed Burton's 1912 patent as infringement claims were filed by Jesse Dubbs and Texaco Company. The strength of this work is placing Burton's innovation within a broad institutional and economic context.
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- Wendt, Gerald L. "The Petroleum Industry." In *Chemistry in Industry*, edited by

H. E. Howe. New York: The Chemical Foundation, 1924. This essay is particularly valuable because it describes clearly the technology commonly employed in the American petroleum industry at the time of Burton's innovation. In addition to excellent sketches of refining and cracking processes and equipment, the various petroleum products commonly marketed during the 1920's are discussed in this nontechnical treatise.

Wilson, Robert E. "Fifteen Years of the Burton Process." *Industrial and Engineering Chemistry* 20 (October, 1928): 1099-1101. Written by a Standard Oil (Indiana) employee, this short article is extremely valuable, for it not only traces early attempts to "crack" petroleum products but also outlines both the economic significance of Burton's innovation and its long-term technological impact. Wilson maintains that Burton's work convinced management of the importance of scientific expertise in controlling and designing refinery operations.

John A. Heimann

### Cross-References

Hughes Revolutionizes Oil Well Drilling (1908), p. 396; Ford Produces Automobiles on a Moving Assembly Line (1913), p. 542.