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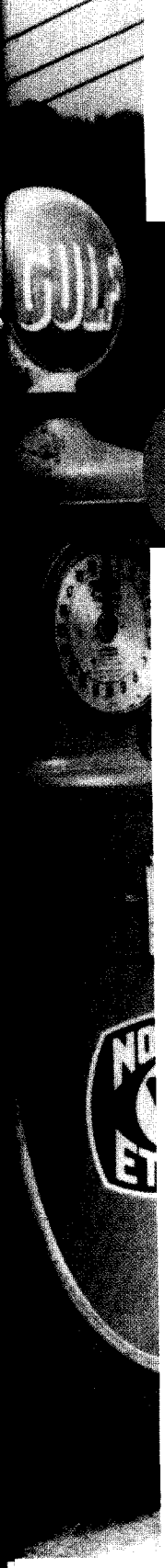
When, in 1907, Professor James R. Bailey of the University of Texas remarked to his organic chemistry students that the Friedel-Crafts reaction was "exceedingly useful," he had no idea just how right he was. One student, at least, was paying attention:



Pioneer of Catalytic Cracking

Almer McAfee at Gulf Oil

Almer McDuffie McAfee made a note in the margin of his textbook about that process of treating petroleum with aluminum chloride. And the jotting remained in his mind: Within only 10 years McAfee, with the support of Gulf Refining Company, would develop the petroleum industry's first commercially viable catalytic cracking process—a method that could double or even triple the gasoline yielded from crude oil by then-standard distillation methods.

Based partly on an 1877 Friedel-Crafts patent, the McAfee cracking process required anhydrous aluminum chloride, a catalyst that was prohibitively expensive. But by 1923 McAfee and Gulf would solve that problem, too, developing a way to synthesize the catalytic reagent at low cost, on an industrial scale. Indeed, each time McAfee's methods appeared to become obsolete, circumstances changed in his favor. Today the results of McAfee's further work with aluminum chloride, which led to the Alchlor process, are still on the scene, proving his innovations not only well-timed, but timeless.

The Right Place, at the Right Time

McAfee had the good fortune to be born near Corsicana, Texas, in 1886. The year he turned 8 marked Texas's first large oil strike—right in his hometown. And when he was 12 years old, the state's first modern oil refinery came to his community, sealing its identity as the original oil boomtown. No wonder that after earning his A.B. in industrial chemistry at the University of Texas in 1908 and his Ph.D. from Columbia University in 1911, he accepted a position with the Texas Company, now Texaco.

Again, timing was on his side. Mass production of the automobile had steadily increased the need for gasoline during the first quarter of the century; by 1911 it was, for the first time, more in demand than kerosene. Until this time naturally occurring kerosene, gasoline, and fuel oil fractions were simply distilled from crude, but limited supply now shook the new transportation economy. Between 1910 and 1913 average gasoline prices leapt from 10 to 30 cents per gallon. Feeling the pressure, refiners pushed to develop new technologies that produced more gasoline from crude.

McAfee was among the first research chemists hired to meet the new challenge. His should have been a cutting-edge work environment; in 1907 the Texas Company had become the first integrated (i.e., producer and seller) oil company to sell more gasoline than kerosene. And indeed McAfee, drawn to gasoline-manufacturing research, arranged in 1912 to become one of the first research chemists on the refinery staff at the Texas Company's facility in Port Arthur, Texas. But despite the financial incentives, the company focused its research more on refining natural gasoline distillate than on developing cracking technology. McAfee was charged with developing a catalytic hydrogenation method

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A Gulf service station, circa 1930. McAfee developed the high-grade gasoline and oil that Gulf marketed as Gulfpride and Gulf No-Nox. Courtesy Chevron Corporation and its subsidiary, Chevron, U.S.A. Inc.

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Gulf tank trucks dating from about 1915, the year McAfee constructed his first commercial process cracking unit at Gulf Oil. All photos courtesy Chevron Corporation and its subsidiary, Chevron, U.S.A. Inc.

for refining distillate stock, to stabilize it, improve its color, and sweeten its odor. With his supervisors 90 miles away in Houston, however, McAfee chose to begin the research that would lead to his life's work on the "gasoline problem."

The researchers brought in to work on the issue focused on two avenues—one leading to thermal cracking, the other to chemical, or catalytic, cracking. In the British patent that inspired McAfee's inquiry—filed in the name of C. D. Abel, on behalf of Friedel and Crafts—low-grade petroleum, heated as a mix with 5% to 20% by weight of anhydrous aluminum chloride, converted the petroleum to light oils, gas, and heavy paraffin oils. McAfee's first contribution to the use of anhydrous aluminum chloride was the careful control of the distillate temperature, which increased the gasoline yield. A Texas crude that used to produce no gasoline could now yield 18%; other crudes doubled or tripled their yields, to about 40%.

But when his superiors at the Texas Company disputed the assignment of patent rights for the process, McAfee sought a position at the company's Port Arthur competitor, Gulf Refining—and took with him his claim to priority in aluminum chloride cracking. Gulf Refining enthusiastically supported development of the process, appointing McAfee project leader and ultimately superintendent of the aluminum chloride department of the company. Gulf also stood behind McAfee's application for an aluminum chloride patent, in competition with those filed by the Texas Company—beginning a series of infringement claims, litigation, and appeals that would be resolved in favor of McAfee and Gulf 15 years later, in 1928.

The first commercial McAfee process cracking unit was constructed at Gulf's Port Arthur facility in 1915—the year Gulf issued its first McAfee process patent—and went into operation in 1916. Now Gulf was ready to advertise the process's technical advantages over its thermal process competitors: The required temperatures were substantially lower, and the reaction could be performed at atmospheric pressure. At operating pressures of 60 to 100 pounds per square inch or higher, thermal cracking produced coke deposits that reacted with the steel of the vessel, causing brittleness in the inner wall. Vessels could—and did—breach, causing fires and explosions. Most important for refiners, the McAfee product had superior color, odor, and anti-knock properties. The octane rating scale had not yet been invented, so Gulf marketed its new high-grade, superior-combustion gasoline as "Gulf No-Nox"; later studies suggested that the octane rating was about 80.

McAfee had devised a very tidy procedure. The crude was heated to remove moisture, then 1% to 5% anhydrous aluminum chloride was added. The 1,000-barrel still operated at 250–280°C (500–600°F) at atmospheric pressure for 24 to 48 hours. Air condensers separated the high-boiling and low-boiling fractions, returning the high boilers to the vessel. And his process had an extra benefit: Because some of the olefin materials were polymerized, the high-boiling material acquired superior lubrication properties. So it was that in 1927 Gulf began marketing a high-grade by-product oil it called "Gulfpride."

Solving the Aluminum Chloride Problem, and More

Although many refiners developed and patented their own aluminum chloride–based cracking processes, the cost of the catalyst remained so high that only one small refiner, the Hoover Company of Enid, Oklahoma, commercialized its patents. McAfee paid $1.50 per pound for the anhydrous aluminum chloride he used in the development stage, in 1913; with 60 pounds of catalyst required to produce 100 gallons of gasoline, his process was of little practical value without a cheap source of anhydrous aluminum chloride.

The Gulf Oil Refinery at Port Arthur, Texas, where Almer McAfee developed his first cracking unit. This photo depicts the refinery in 1901, fourteen years before McAfee joined Gulf.

It took McAfee three years—and the Gulf Company an investment of $1 million—to develop a practical way to synthesize anhydrous aluminum chloride on a large scale. By 1923 the McAfee aluminum chloride process had reduced the cost of producing it to three cents per pound. By the mid-1920s Gulf had built a total of twenty-seven 27,000 barrel McAfee cracking-process stills at Port Arthur, and three identical stills at its Fort Worth refinery. To meet just its own demand for aluminum chloride, Gulf opened the largest plant in the United States producing chlorine and caustic (sodium hydroxide) by electrolysis, at Port Arthur in 1925. Between 1924 and 1929 the Port Arthur refinery produced more than 90% of the anhydrous aluminum chloride synthesized in the United States, peaking at a capacity of 75,000 pounds per day.

But there was soon competition. By the late 1920s engineers had improved high-temperature and pressure-cracking operations, reducing the cost of thermally cracked gasoline. Even with its catalyst made cheaper, the McAfee cracking process could no longer compete economically. In 1929 Gulf stopped operating the process—the only exception to the dominance of thermal methods in the industry. (Yet almost simultaneously, a team of French inventors led by Eugene J. Houdry was starting a prototype plant for lignite catalytic cracking in France. Later, in 1936, Houdry's work would lead to the second commercially viable catalytic-cracking method.)

Still, McAfee was not out of the running. With the open market price of aluminum chloride at 12 cents per pound, McAfee announced in mid-1929 that Gulf would make available carload lots of anhydrous aluminum chloride at 5 cents per pound. Professor Bailey's pronouncement that Friedel-Crafts chemistry was "exceedingly useful" now became industrial reality. An editorial in *Industrial and Engineering Chemistry* in August 1929 took note, stating,

> In many a laboratory the long list of Friedel and Crafts syntheses, worked out and described some fifty years ago, will now be reinvestigated from the standpoint of commercial utility, since at last aluminum chloride is available in carload lots. . . . Those who make fundamental reagents available to industry at a cost permitting more extensive use perform services the beneficial effects of which will be felt for many a year to come.

McAfee also devised methods to use aluminum chloride as a reforming catalyst, where straight-chain hydrocarbons from the cracking process are structurally rearranged to higher octane branched chain hydrocarbons. His process for the production of lubricating oils became generically referred to as the Alchlor (abbreviated from aluminum chloride) process. In November 1934 Gulf began large-scale production of its "Gulfpride Oil" using that very process. McAfee's work, then, was never really outmoded: While his cracking processes are no longer used commercially, Alchlor reforming and lubricating-oil refining are still with us today. ⚙

The Gulf Oil Refinery at Port Arthur, Texas, in 1926.