Consensus Standards Drove Automotive Fuel Innovation

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Abstract

Gasoline-powered internal combustion automobiles have formed the backbone of the American transportation industry for close to a century. The petroleum mining and refining industry is increasingly global, with every oil well producing crude with different characteristics and composition. Thanks to the early-1900s developments of consensus standards with regards to the testing and characterization of gasoline, consumers are guaranteed fuel performance and reliability regardless of their fuel's origins. This paper examines the development and impact of those consensus standards on the automotive industry in the United States, demonstrating that innovation occurs when industries cooperate.

The vast majority of modern automobiles are powered by internal combustion engines and fueled by either gasoline or diesel, but the earliest years of automotive transport were not characterized by such a market dominance. From the 1890s to the 1900s, when internal combustion engines ran on kerosene or grain alcohols as often as gasoline, many people believed that electric carriages and omnibuses were the future of transportation – a prediction which failed to come true. Instead, internal combustion engines powered by gasoline became the *de facto* standard for personal automobiles [1, p. 29]. From 1864 to the late 1960s, gasoline's composition, desired characteristics, and methods of testing were all governed only by consensus standards established within the automotive industry. These standards, which often grew out of collaborative research and development, have been the source of tremendous innovation within the transportation industry – allowing billions of cars to operate without a hiccup on fuels mined and refined from all over the world. The history of standardized gasoline is a heretofore untold story that holds important lessons for global innovation in the 21st century.

Today, the U.S. Environmental Protection Agency defines gasoline as a petroleum distillate with high volatility that is able to conform to a variety of emissions standards when combusted in approved combustion systems [2]. Since the mid-1970s, regulators have characterized gasoline by its emissions standards. From the 1860s to the 1970s, however, gasoline had no federal definition. It was a substance defined only by the consensus standards of the automotive and petroleum engineers who dealt with it frequently. The term "gasoline" has its roots in "gazeline," a knockoff of petroleum-distillate called "Cazeline oil" sold in the British Isles in the 1860s [3], [4]. One of the first indexed instances of the word "gasoline" in a relevant American publication occurred in 1899 in the *Journal of the Society of Chemical Industry,* announcing an English patent titled "Gasoline Gas Apparatus or Carburettors [sic]" [5].

Early petroleum distillation (the process by which a multicomponent fluid is separated into multiple fluids with varying volatilities) was optimized for the production of kerosene, which is in the middle range of petroleum volatility. Gasoline, which described the lightest distillates, was generally considered a waste product up until the 1920s, when engineers noticed its favorable properties as an automotive fuel [6, p. 117]. By 1915, the demand for gasoline vastly outpaced that for kerosene. The expanding automotive market created high demand for new methods to improve the yield of gasoline from petroleum distillation. Due to the varied petroleum wells and distillation methods in use, even fuels bearing the same brand did not necessarily have similar attributes. For instance, a comparison of seven different British petrols (gasolines) tested in 1909 revealed extremely different characteristics: the lowest distillation point of these fuels was 55° C and 73% had vaporized at 100° C, whereas the highest distillation point was 70° C and only 39% had vaporized at 100° C [7]. While these large discrepancies naturally lessened as empirical evidence revealed the best methods of petroleum distillation and cracking, American engineers did not develop any form of specifications or regulations for gasoline until the 1910s.

In the mid-1910s, U.S. Secretary of the Interior Franklin Lane tasked the U.S. Bureau of Mines with preparing specifications for gasoline to be purchased by the federal government [8, p. 17]. The Bureau announced in 1916 that it would publish a “guide for the public” for gasoline specifications [9]. The task of preparing that report was assigned to E.W. Dean, a Bureau of Mines employee who was also a representative of the Society of Automotive Engineers (SAE). Dean published the document in May 1917. It outlined the most important characteristics for consumers to consider in gasoline purchases [8], and, more importantly, described three key parameters to determine gasoline quality for federal purchases: color, acidity, and volatility. Dean provided only vague specifications for each of these qualities, but he concluded the report with proposed testing procedures with a strong emphasis on the most important aspect: volatility [8, pp. 17–23].

Volatility, in chemical terms, is the tendency of a liquid to evaporate at any given temperature and pressure. Though gasoline is stored in liquid form, its combustion progresses in the vapor phase. Thus it must be evaporated or vaporized prior to its utilization in the engine. Gasoline, which is more volatile than kerosene, is more readily vaporized, making it easier to use in an internal combustion engine. Throughout the 1910s and most of the 1920s, volatility was the most important factor in determining gasoline quality, but it was difficult to measure. It was the *mot juste* at the time that “the only adequate test for gasoline or any other petroleum product (was) that of actual use” [8, p. 5]. The best laboratory method available was the “Engler method." The Engler method is a simple distillative test: a distillation flask is heated with a burner or electric heater, the distilled vapors are condensed using an ice bath insulated with asbestos boards, and the temperature is measured on both sides by cotton-swabbed thermometers [10], [11, p. 396]. However, because gasoline is utterly nonhomogenous, and the Engler method can only be used on small samples, it was of little use in the broad testing of automotive fuels.

Two of the parameters the Engler test did measure are called the start and end distillation points, which are the temperatures at which distillation begins and concludes. The range of start-points and end-points in commercial gasoline made it extremely difficult for automotive engineers to design engines capable of running on all gasolines. By and large, this issue was addressed by heating the engine's intake manifold, which became the standard method of pre-heating fuels prior to ignition in the engines' combustion chambers. To maintain the overall efficiency of the engine, the manifold was heated using waste heat from elsewhere in the engine – generally from the hot exhaust gases [12, p. 171]. This approach, known as a "hot-spot manifold," was extensively researched by the SAE in 1919. The results showed marked improvements to fuel economy provided that the hot-spot temperature didn't exceed 800-1000° F. Higher temperatures could result in the fuel leaving solid deposits on the manifold [12, p. 173]. Though this innovation, which was quickly adopted across the automotive industry, made it feasible for a car owner to purchase virtually whatever gasoline he pleased, it did not ensure uniform engine efficiency for all fuels. As such, some automobile owners took to modifying their engines, particularly by tuning their spark plugs, to reduce the engine vibrations (knock) or increase efficiency due to their specific fuel source [13]. To remove the impetus for automobile owners to tinker with their machines, the industry leaders realized that further consensus standards quantifying gasoline quality were required.

To address the various problems associated with automotive fuels, in 1919 the SAE formed a committee called the "Cooperative Fuels Research Committee" (CFRC) [13], [14]. The main goals of the committee's first meeting, in September 1919, were to determine a list of the prominent issues related to fuels and provide recommendations for universal gasoline specifications and protocols for standardized fuel testing [13, pp. 360–1]. The problems the

CFRC identified were all due to the "failure to overcome the difficulty of vaporizing fuels which have a wide range of boiling points or a steep distillation curve." [13, p. 359]. As such, they strongly recommended some kind of consensus standards for gasoline distillation curves and for a standardized apparatus or method for testing volatile fuels

Throughout the 1920s, the CFRC published a number of reports on the volatility of various gasolines and kerosenes sold across the United States, each of them calling for a higher level of standardization to deal with the unreliable distillation curves [15, p. 27], [16, pp. 142–45]. To aid in this research, in 1922 the Interdepartmental Petroleum Specifications Committee, founded in 1918 by President Woodrow Wilson on the basis of E.W. Dean's aforementioned report, published a comprehensive handbook for petroleum distillate testing and characterization protocols [10], [17]. While these protocols, as well as those published by the CFRC in 1926, were a step in the right direction, they did not obviate the need for a better testing apparatus to ensure reproducible, reliable, and easily understandable results [11, p. 396]. To that end, many members of the CFRC collaborated in designing a novel, proprietary, one-cylinder fuel-testing engine [18]. The engine, released in 1929, is commonly known as either the "Waukesha CFR engine" in honor of its manufacturer, Waukesha, or simply as the "CFR engine" in honor of the CFRC. Though the design and components of the CFR engine have been modified over the past 85 years, it remains the standard testing instrument used internationally, and is still manufactured by Waukesha [19, p. 141], [18].

Upon its demonstration at the 1929 SAE meeting, the CFR engine was incredibly popular. By 1920, researchers in Britain were requesting a unit for their own research and testing – a crowning achievement in an era when international automobile standards were incredibly rare [20, p. 267]. The CFR engine, in conjunction with two standard reference fuels – isooctane and heptane – allowed for a consensus standard method of determining the most prolific measurement of volatile fuel quality: the octane number [21], [22]. The octane numbers now seen at gasoline stations worldwide are actually composed of two numbers, the Research Octane Number (RON) and the Motor Octane Number (MON), which are each measured on different variants of the CFR engine [22], [23]. For decades after the CFR engine's release, octane numbers were consensus standards, used worldwide as a means of measuring gasoline quality. The federal government continued to issue revised specifications for its own purchases of gasoline, but there were no limitations or standards put in place for gasoline sold commercially [24], [25]. The consensus adoption of octane numbers to determine gasoline quality improved the market for consumers, allowing them to gauge the relative quality of fuels with very little technical knowledge.

During World War II, the demand for high-octane gasoline increased precipitously. Though the octane rating was well entrenched in the industry, the production methods could not keep up with demand. A French chemist named Eugene Houdry provided the solution: a new means of catalytic gasoline production [26]. The Houdry process produced 50% high-octane gasoline from virtually any petroleum source, whereas conventional steam cracking and fractional distillation could produce 20 to 25% at best [26]. This, in Schumpeterian terms, is an innovation of new methods of production [27]. The surge of available high-octane fuels after the war essentially stopped the discourse about federal regulations for gasoline. In 1971 the Federal Trade Commission issued what was called the "Octane Rule," which mandated that gasoline manufacturers use American Society for Testing Material (ASTM) standards (involving the Waukesha CFR engine) to determine the octane number for all fuels to be sold in the United States [28], [29]. It is key to note that this rule did not require any particular octane levels be sold, merely that sellers advertise the octane rating of their gasoline – thus standards were still not being set for the quality of gas being sold, only that the quality be apparent.

For its entire history, methods of gasoline production have been determined by industry consensus. A few compositional regulations of gasoline, mostly dealing with lead content, were imposed over the course of the 20th century, but just as the definition of gasoline arose from the consensus of those who made and used it, so too did the standards defining its composition. The innovative development of the Waukesha CFR engine came out of a community drive for enhanced testing methods that resulted in incredibly useful consensus standards. Gasoline sales went unregulated in the U.S. for roughly a century, until a consensus-derived standard for quality determination was made mandatory. Virtually every aspect of the personal transportation industry has been shaped and influenced by these consensus standards since the 1910s, and they have never failed to meet industrial needs.

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