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ALLIANCE OF AUTOMOBILE MANUFACTURERS

WHITE PAPER:

WHY EPA TIER 3 MARKET GASOLINE SULFUR LIMITS NEED TO BE SIGNIFICANTLY LOWER, ESPECIALLY FOR MY 2017+ VEHICLES

Introduction

EPA is preparing to propose a new Tier 3 regulation by the end of 2011, one component of which would reduce the average level of sulfur in marketplace gasoline below the existing Tier 2 sulfur standard. The members of the Alliance of Automobile Manufacturers have been engaged with the Agency to express their vital interest in the content of the proposal, and to underscore support for a meaningful reduction in retail market fuel sulfur content nationwide.

EPA's current Tier 2 market gasoline sulfur standard essentially imposes three limits:

- 30 ppm maximum annual average at the refinery gate;
- 80 ppm per gallon maximum/cap at the refinery gate, measured on a batch basis;
- 95 ppm per gallon maximum/cap at the retail fuel pump.

The Tier 2 gasoline sulfur regulation was promulgated in 2000. Starting in 2004, for the six years of the implementation phase in, EPA provided a generous amount of flexibility to oil companies, including: corporate-wide averaging, inter-refinery trading, small refiner exemptions, a slower phase-in for Rocky Mountain region facilities, and a mechanism for hardship waivers, among others. In the aggregate, these have had the effect of "masking" some chronically high sulfur market gasoline supplies in certain areas, which cumulatively may have adversely affected vehicle catalyst performance and durability, and emissions in those markets.

The specific new Tier 3 vehicle emissions limits, and changes in fuel sulfur limits, are still in development. It has been suggested that EPA is considering reducing the individual refinery annual average maximum from 30 ppm to 10 ppm. However, EPA is also considering the implications of retaining the existing per gallon caps (80 ppm refinery gate; 95 ppm retail pump) versus lowering them (*e.g.*, to 20 and 25 ppm, respectively). This White Paper explains why a proposal to keep the 80/95 ppm Tier 2 sulfur caps is adverse to Agency goals for the auto industry.

It is also critical that in designing Tier 3, EPA not unduly delay uniform sulfur limits at the retail pump, by providing another set of flexible compliance measures to refiners as were used in Tier 2. The Alliance does not oppose flexibility for the oil industry *per se*, but the retail gasoline provided should be compatible with Tier 3 vehicle needs in order to meet both fuel economy/GHG requirements [including pending new limits for MY 2017[1]] and pending Tier 3 emissions reductions. The new lower sulfur fuel must be in the marketplace nationally for these vehicles in a timely manner to protect the vehicles, consumers, and the environment.

High sulfur cap limits and/or over-broad implementation flexibility (*e.g.*, in calculating averages across refineries) that allow a wide and unpredictable range of actual sulfur content among different geographic areas and over time, will handicap automakers' ability to introduce new advanced technology systems needed to meet the pending 2017 Fuel Economy/GHG regulations and maximize reductions in vehicle emissions. This approach would fail to treat the vehicle and the fuel as a system, and put an unfair proportion of the total regulatory burden on the auto industry.

Sulfur's Adverse Impact on Current and Future Emission Controls

Gasoline sulfur poisons all types of vehicle emission control devices and reduces their ability to reduce tailpipe emissions. For the three-way catalysts (TWC) used on nearly all existing gasoline-powered light duty vehicles in the U.S., the reduced efficiency caused by sulfur poisoning requires automakers to over-design their vehicles (if/when possible to do so) to meet emission standards. This over-design often involves the increased use of expensive and scarce precious metals in the catalyst, which ultimately makes the vehicle more expensive (and prone to catalyst theft). Furthermore, if the sulfur level is high enough, such design compromises may not be possible.

In all cases, even where over-design enables a vehicle to meet its emission standards, the actual emissions from a vehicle with a sulfur-poisoned catalyst will be higher than they otherwise would be. Since chronic sulfur poisoning may be only partially reversible, the impact on catalyst efficiency is cumulative. Thus, all conventional emissions—including HC, CO, NOx, PM and toxics—will increase as a result, depending on the amount and duration of the sulfur exposure. Sulfur also will affect the vehicle's fuel economy and greenhouse gas emissions adversely, due to the additional energy and operational steps that need to be taken to cope with the sulfur poisoning.

The reversibility of the poisoning, especially over time, in a vehicle chronically exposed to higher sulfur retail gasoline, is an important issue. When the Tier 2 regulation was adopted, it was believed that the sulfur poisoning could not be reversed without physically replacing the catalyst.[2] Over time, technology improvements did enable some reversibility, although at a cost of lower fuel efficiency.[3] Even so, sulfur will always cause at least some permanent impairment of the catalyst, and this impairment causes increased concern as the vehicle accumulates mileage, and as emission standards become more stringent. Under Tier 2, vehicles must continue to meet emission standards through 120,000 miles of driving, and the Tier 3 regulation is anticipated to require compliance with tougher standards of driving.

Reversing the sulfur poisoning requires very high temperature operation from time to time, but TWC subject to leaner exhaust hydrocarbon levels will have lower operational temperatures, making them easier to become and remain poisoned with sulfur. In addition, over time, repeated

[1] New models are introduced during the previous calendar year, *i.e.*, MY 2017 vehicles are introduced during CY 2016.
[2] As a compliance measure, replacing the catalyst is prohibited.
[3] Removing sulfur from TWC requires increasing the fuel-air ratio and higher temperatures, among other things.

burn-off of the catalyst can damage the catalyst brick substrate, prematurely age it, and reduce catalyst durability.

Highway driving tends to produce higher exhaust temperatures than city driving, and if a vehicle is driven only in the city, its catalyst may not see the higher temperatures needed for sulfur burn-off, and as a result its emissions will be higher. Many, if not most, of these city vehicles will be located in ozone non-attainment areas. EPA should consider that many consumers may drive in a manner not conducive to catalyst burn off, yet are located in areas that need the emission reductions the most.

New technologies are under consideration as tools to help automakers meet stringent new fuel economy standards, and the significantly more fuel efficient, lean burn gasoline engine (compared to conventional engines) is one of these. This technology requires the use of different emission control devices, such as the Lean NOx Trap, similar to those used in diesel engines, to meet NOx emission standards. Lean NOx traps also have lower operational temperatures and will be more easily poisoned. These devices quickly and permanently lose their ability to function as the fuel sulfur level rises above 10 ppm.[4] Some of the individual automakers have already provided EPA with proprietary company-specific data on this point.

Recent Support for Reducing Sulfur: SAE 2011-01-0300, D. Ball, et al., *Effects of Fuel Sulfur on FTP NOx Emissions from a PZEV 4 Cylinder Applications*

Test data on sulfur's impact on very low emitting vehicles (*e.g.*, SULEV, PZEV, and Tier 2-Bin 2) remain scarce, especially at ultra-low sulfur levels and over a 150,000 mile compliance lifetime. This recent SAE study provides some insight. The authors measured the impact of test fuels containing 3 ppm and 33 ppm sulfur on NOx emissions from a 2009 MY PZEV Malibu. One important aspect of the evaluation was measuring the ability of different driving cycles to reverse the catalyst poisoning, and the potential for "NOx creep", *i.e.*, the incremental permanent reduction in catalyst efficiency as a result of repeated sulfur exposure. As the study notes, catalyst efficiencies for PZEVs need to exceed 99.4% for HC and 99.3% for NOx through 150,000 miles, and small changes in catalyst efficiency can have a large impact on tailpipe emissions.

The study found that sulfur levels of 33 ppm will affect "test to test" NOx stability during FTP testing, and that catalyst temperatures of 600°F, common in under-floor catalysts, can allow sulfur poisoning that affects NOx reduction efficiency and consistency of results. Using the US06 test cycle (high engine flow, high load) between FTP cycles, however, can increase catalyst temperature enough to help reverse the poisoning and improve "test to test" stability. According to the study, while the US06 can help mitigate sulfur poisoning, using a 3 ppm sulfur gasoline would eliminate the need to use such a cycle -- also, a 3 ppm fuel would reduce NOx emissions by 40% compared to the 33 ppm fuel, and/or allow lower levels of precious metals in the catalyst.

[4] In 2000, the Association for Emissions Control by Catalyst (AECC) found: "The promising NOx adsorber technology that diesel and lean burn engines need requires sulphur levels significantly below 10 ppm. This will avoid compromising the lower fuel consumption and CO2 emissions by requiring frequent regeneration to remove the sulphur that is clogging the NOx adsorption capacity. See *Response to European Commission Consultation on the Need to Reduce the Sulphur Content of Petrol and Diesel Fuels below 50 parts per million*, July 2000, available at http://www.aecc.eu/en/Publications/Archive.html.

Lessons from Tier 2 US Gasoline Sulfur Regulation

Automakers found Tier 2 vehicle emission regulations much more stringent than expected, which in turn strengthened their call for the lowest possible gasoline sulfur levels. The Agency's choice of nominal 80 ppm/95 ppm sulfur caps for Tier 2 was already a much bigger compromise than should have occurred.

In addition, EPA's Tier 2 implementation scheme allowed sulfur levels to be significantly higher in the marketplace than the nominal legal limits for a considerable period after the rule's adoption. Besides giving most refiners two years after the 2004 effective date to phase in to the standard, the Agency gave an additional two years to small refiners and those in the Rocky Mountain region, and refiners could apply for hardship waivers that would allow an additional two years to comply. Thus the rule actually allowed six years to fully phase in the new fuel quality, with no provision to prevent local high sulfur areas during this period.

Moreover, EPA's 30 ppm limit was reached by averaging all batches *over a full year*, compared to California's low sulfur regulation (RFG Phase 2, implemented in 1996) which required averaging over a six month period. EPA imposed its 80 ppm per gallon cap at the *refinery gate*, and allowed retail gasoline to reach a 95 ppm cap at retail (and even this limit did not become absolute until 2011). California's Phase 2 regulation imposed its 80 ppm per gallon cap *at retail.* In its North American Fuel Survey (NAFS) the Alliance of Automobile Manufacturers was still finding U.S. retail gasoline with sulfur as high as 148 ppm in the summer of 2010.[5] While automakers would strongly welcome a significant lowering of average sulfur levels, they are greatly concerned about the possibility of high sulfur "hot spots" persisting at various retail points around the country if high caps are still allowed.

It is unclear when EPA will next revisit the issue of sulfur market fuel specifications, so the Agency should propose limits that will enable nationwide introduction of all emerging vehicle technologies for the foreseeable future.

Implications of Retaining the Tier 2 Sulfur Caps

Even with a much-needed, much lower annual sulfur average per refinery in place by 2016 (for MY 2017 vehicles) (and assuming no Tier-2 type averaging flexibility), retaining the *current* Tier 2 sulfur caps (80/95 ppm) in Tier 3 would be extremely problematic for autos, given the challenges of the 2017-2025 Fuel Economy/GHG rule and pending Tier 3 vehicle emission standards. Even if EPA reduces the refinery annual average sulfur limit considerably below the current 30 ppm, the prospect of continuing to allow up to 95 ppm sulfur *retail* gasoline in the marketplace means consumers in some locations will be buying relatively high sulfur fuel for their vehicles, some of them on a regular basis.

In addition, automakers are very concerned about repeated exposure of such vehicles to high sulfur levels, because the accumulation of sulfur on their catalysts over time and miles will put them at an unfair (and unpredictable) disadvantage for in-use compliance testing. Under Tier 2

[5] The Alliance of Automobile Manufacturers North American Fuel Survey (NAFS) conducted in the summer of 2010 found regular gasoline in Kansas City containing 148 ppm sulfur. However, the first NAFS survey for 2011 (conducted in January 2011) showed all gasoline samples apparently compliant with the 95ppm sulfur retail standard.

standards, vehicles must comply with emission standards for 120,000 miles of driving (and many vehicles are in Sec. 177 states requiring *California* emissions limit compliance for 150,000 miles, but which are exposed to *federal* fuels rather than the benefit of California fuels). Under the Tier 3 rule, automakers anticipate that all vehicles will be required to comply with tighter emissions standards. Many will need to comply with the longer California useful life criterion. In addition, long-term usage patterns (e.g., predominantly urban driving versus high-load highway driving) will differently affect catalyst performance and durability. Adding the element of unpredictable levels of market fuel sulfur (geographically and over time) could affect future in-use testing results, especially if no sulfur preconditioning steps are applied.

Vehicles have reduced catalyst efficiencies during and after chronic higher sulfur exposures, and this can cause significantly higher emissions. Poor or incomplete reversibility will cause ongoing higher emissions wherever the vehicle travels, including ozone non-attainment areas. Furthermore, future gasoline is likely to contain more ethanol, which contributes to higher NOx emissions, so higher sulfur gasoline will exacerbate the likelihood of an emissions increase. These combined effects would set back state efforts to meet stringent ozone ambient air quality standards. Importantly for the states and the general public, even occasional vehicle exposures to sulfur levels as high as 95 ppm will cause significantly higher HC, NOx, PM and toxic emissions than the design capability of vehicles. As a result, EPA will risk failing to prevent air quality backsliding, which Congress required EPA to study specifically out of concern about ethanol's impact on emissions.[6]

Allowing retail sulfur levels as high as 95 ppm also will inhibit the introduction of new fuel efficient, lean burn gasoline engine technology, as already publicly noted by some automakers. These engines are capable of providing significantly improved fuel economy and greenhouse gas benefits compared to conventional engines, but they require emission control devices that are quickly poisoned as the fuel sulfur level rises above 10 ppm.

Countries and regions that have capped gasoline sulfur at 10 ppm (for example, Europe and Japan) have been able to enjoy the benefits of lean burn technology over the past decade. If EPA retains the 95 ppm retail cap, U.S. consumers will continue to be deprived of this fuel efficient option, and they will continue to wonder why other countries seem to have more advanced and a greater diversity of fuel efficient technologies than the United States.

Maintaining a 95 ppm retail sulfur cap would be damaging to the U.S. reputation as a leader in air pollution control because so many other countries and some cities have already achieved ultra-low sulfur levels in their gasoline.[7] In Canada, for example, according to the Alliance's North American Fuel Survey, the highest sulfur level recorded last summer (2010) was 32 ppm for regular grade and 20 ppm for premium, and since 2007, the levels there have been consistently below 40 ppm. In Mexico all premium grade samples in the Alliance surveys have had less than 52 ppm sulfur since 2007. In half of the cities sampled, regular grade samples have had less than 80 ppm sulfur since 2009.

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6. *See* 42 USC 7545(q). Though due in draft form by 2009, this analysis has not yet been published. EPA expects to work on this analysis in parallel with drafting the Tier 3 Proposed Rule.

7 According to Hart's International Fuel Quality Center, as of May 2010, Japan, South Korea, Iceland, Greenland, and the countries of the European Union require less than 10 ppm sulfur gasoline. The U. S. ranks 44th in a ranking of the top 100 countries by gasoline sulfur standard stringency. *See* PR Newswire, "IFQC Ranks Top 100 Countries by Gasoline Sulfur Standards: Europeans' Major Progress Bumps U.S. to 44th Place," May 5, 2011, and IFQC, http://www.ifqc.org/NM_Top 5.aspx.

Automakers that engineer vehicles for the U. S. have waited a long time for lower fuel sulfur levels that harmonize with foreign standards, enable lean-burn technology, and make full use of advanced technologies. Maintaining existing U.S. high sulfur caps would inhibit needed technology and international harmonization of fuels and vehicle design, and waste scarce economic and commodity resources on over-sophisticated emission control systems.

Flaws in the Purported Reasons for Retaining the Tier 2 Sulfur Caps

The main argument against more stringent sulfur limits boils down to concern that a few, perhaps older or small refineries that supply U. S. retail gasoline might be unable to consistently produce a lower sulfur product.

This argument seems weak, given how long refiners have known about sulfur's effects and have been producing lower sulfur gasoline. As noted, California began requiring a low sulfur gasoline in 1996. In 1998 EPA imposed Federal RFG Phase 2 requirements—affecting about one third of the country's gasoline market. To comply with federal RFG2's required NOx reductions, refiners needed to substantially reduce sulfur. As a result, by 2000, refiners were well on their way to producing Tier 2 compliant gasoline, as shown in EPA's Fuel Trends Report 2008, which studied retail sulfur levels from 1995 to 2005. By 2005, several years after Federal RG2 implementation and one year after Tier 2 implementation, the Federal RFG summer retail average had already dropped to about 70 ppm from about 200 ppm in 1998. The annual average for all gasoline in 2005 was 92 ppm. It is very difficult to conclude that a lower sulfur retail limit would not be feasible in the U.S. A few stressed refineries should not drive the universally applicable prospective federal limits.

A second argument is that contamination during distribution through the finished product pipeline infrastructure contributes to retail gasoline sulfur levels and that this contamination cannot be further controlled. The Alliance would appreciate the opportunity to see what current data EPA or other stakeholders have, including any comparisons of past versus current samples showing the relative magnitude of sulfur contamination levels, or that support the need for a 95 ppm sulfur retail cap.

The same contamination concerns were voiced when EPA was developing the ultra-low sulfur diesel (ULSD) fuel standard in 2002. Yet the country has successfully converted to retail 15 ppm sulfur diesel fuel nationwide, using the same pipelines to distribute the fuel as used for gasoline. Further, since the 2002 ULSD rule, EPA has greatly reduced the sulfur levels in other petroleum products that move through the pipelines. Non-highway diesel fuel and fuel used for locomotive and marine applications will have to meet the same 15 ppm sulfur limit by 2014, before Tier 3 is implemented. Thus, it should be much easier to move ultra-low sulfur gasoline in pipelines in 2016-17 than it was in 2006, when ULSD began its phase-in. In addition, since most gasoline today contains 10% ethanol, the sulfur levels are further reduced (diluted) during blending after the fuel leaves the pipeline, which also provides refiners with some flexibility.

EPA Opportunity to Promote International Harmonization Regarding Sulfur Levels

The 2000 edition of global automakers' Worldwide Fuel Charter stressed the need for sulfur-free gasoline. Shortly afterward, Europe and Japan started moving toward a 10 ppm maximum sulfur standard. Both of these markets have now had ultra-low sulfur gasoline for several years. Other countries, including Canada and Mexico, also are moving to well below 80 ppm[8] consistent with

[8] Based on retail sulfur levels measured through the Alliance North American Fuel Survey, 2007-2011.

the goals of the UNEP-managed Partnership for Clean Fuels and Vehicles, in which both EPA and the oil industry participate.[9] In 2005, the PCFV conservatively recommended a 50 ppm sulfur limit for all countries, even those in Africa, while recognizing the benefits of further reduction, but keeping in mind the challenge presented for developing countries.

Conclusion

EPA should use its opportunity in Tier 3 to provide a strategy toward achieving a 5-10 ppm cap on sulfur in U.S. retail gasoline. Any issues relating to particular refinery capability, pipeline, or other sulfur contributions should be addressed individually, as part of the larger strategy to achieve this goal, but should not be used to change the goal itself. Allowing sulfur caps as high as 80 ppm at the refinery gate and 95 ppm at retail pumps to continue indefinitely in the US marketplace is unwarranted, would handicap maximizing vehicle emission reductions and achieving fuel economy and GHG standards, and would inhibit development and use of cleaner, more efficient combustion technologies.

The Alliance looks forward to additional opportunities to work with EPA and other stakeholders on the gasoline sulfur reduction challenge.

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[9] *See* Partnership for Clean Fuels and Vehicles, http://www.unep.org/transport/pcfv/partners/partners.asp); and Low Sulphur Campaign, http://www.unep.org/transport/pcfv/corecampaigns/campaigns.asp#sulphur). In 2005, the Partnership recommended that countries aim "To reduce sulphur in vehicle fuels to 50 ppm or below worldwide, concurrent with clean vehicles and clean vehicle technologies, with roadmaps and timelines developed regionally and nationally". *See* Summary of the Fourth Meeting of the Global Partnership for Clean Fuels and Vehicles, UNEP Headquarters, Nairobi, Kenya, 14-15 December, 2005, available at http://www.unep.org/transport/pcfv/PDF/4GPM-report-final.pdf.