
According to AAM, reducing the Sulfur cap will improve fuel economy by enabling Lean Burn GDI engine technology

We question the assertion that a 10 ppm gasoline sulfur cap would have any significant impact on the utilization of lean burn gasoline direct injection (GDI) engine technology. In regions of the world where 10 ppm sulfur in gasoline was mandated (i.e., Europe and Japan), the penetration of lean-burn GDI peaked at 2% and has been declining thereafter. Data show that the AAM statement that “…Europe and Japan have been able to enjoy the benefits of lean burn gasoline over the past decade” is inaccurate. The real-world efficiency benefits of lean-burn GDI were found to be less than promised.

EPA, DOT and others have recognized that lean-burn GDI is a strategy that the automakers are unlikely to adopt in large scale for compliance with the Corporate Average Fuel Economy and tailpipe greenhouse gas emissions standards currently in place.¹ A recent assessment of the automakers’ technology introduction plans concluded that: (a) the opportunity for lean GDI in the US is limited to 0-3% market penetration by 2020, and (b) 10 ppm max sulfur in gasoline will not result in lean burn engine production.²

According to AAM, regulatory flexibility (similar to the Tier 2 phase-in) should not be allowed for the refining industry

AAM states that sulfur “hot spots” have occurred in certain regions due to the flexibility granted by EPA to small refineries with respect to meeting the Tier 2 gasoline standard over an extended time frame. AAM barely acknowledges (and only in a footnote) that this regulatory flexibility ended at the close of 2010. The most recent AAM fuel survey data (for the winter of 2011) show no gasoline samples exceeding the 95 ppm sulfur cap at retail. In fact, according to this recent AAM data, 96% of US gasoline at the retail level now contains less than 50 ppm sulfur. The adoption of a flexible “systems-based” regulatory approach is what helped to assure the success of the Tier 2 program by giving the automakers 5 years to phase in the production of Tier 2 compliant vehicles and a nearly commensurate amount of time for certain small refineries to comply with the fuel requirements.


AAM states that a 10ppm cap is necessary for air quality needs

Emissions reductions from advanced technology vehicles – There is an abundance of information that characterizes the effects of reducing gasoline sulfur on the exhaust emissions from many automotive technologies represented in the current on-road fleet (e.g., up to and including Tier 2-certified vehicles). This extensive database shows that reducing sulfur lowers emissions of HC, CO and NOx, linearly. However, as AAM correctly observes, test data on the effect of sulfur on very low emitting vehicles such as those certified to PZEV, SULEV and/or Tier 2/Bin 2 emissions standards remains sparse – an observation made all the more poignant by the fact that the AAM White Paper could only point to one publication on these vehicle technologies: a study performed by D. Ball et al, Umicore Autocat USA, Inc., that evaluated the emissions reductions associated with reducing sulfur from 33 ppm to 3 ppm.

Only one vehicle was tested by Ball et al: a 2009 model year vehicle certified to California’s partial zero emission vehicle (PZEV) standards. Aside from the fact that a single vehicle is hardly representative of the range of automotive technologies currently in (or planned for) production, the study’s conclusion that the claimed 40% reduction in NOx was due solely to differences in test fuel sulfur content is not well supported. In particular, Ball et al provide no information on the properties of the two fuels tested other than stating the differences in sulfur. This omission of information is critical. Based on historical analyses of fuels with label names (e.g., “CARB phase II certification fuel” and “EEE-Lube certification fuel”) similar to those described in the Ball et al paper, we believe that there were variations in other properties of the test fuels (especially oxygenate type/concentration and fuel distillation parameters), and these almost certainly would have confounded the results.

As indicated above, a one vehicle study is hardly statistically insignificant; yet we know from the extensive extant database that sulfur impacts and sulfur reversibility effects are highly dependent on several test parameters, including the vehicle and technology being evaluated and the driving cycle being used. The results for this one particular test vehicle are especially difficult to fathom for they show the emissions generated during fully warmed up driving operation to be higher than those generated when the engine is started cold. This is the opposite of what is generally expected for vehicles designed to meet extremely stringent emissions standards such as those for the PZEV.

Finally, Ball et al found that the catalyst poisoning effect associated with the use of gasoline with 33 ppm S in a PZEV was clearly mitigated by vehicle operation between tests at the

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5 For instance, CARB Phase II Certification gasoline contains 11 vol % MTBE while “EEE-Lube certification fuel” contains no oxygenates of any type. Also, CARB Phase II Certification gasoline typically has a vapor pressure of 6.7 – 7.0 psi while that for the “EEE-Lube certification gasoline is typically in the 9 psi range.
different sulfur levels over a broader range of real-world driving conditions (i.e., as embodied in the US06 test cycle) than found on the standard FTP cycle. The authors then infer that the need for such a cycle would be eliminated by reducing gasoline sulfur from 33 ppm to 3 ppm. Such reasoning is specious due to the fact that fuel parameters other than sulfur were allowed to vary, thus confounding any interpretation of the results.

**EPA Certification Data – AAM argues that 10 ppm sulfur is necessary for vehicles that will be designed to meet the Tier 3 emissions standards that are currently being considered, and those standards are essentially equivalent to today’s federal Tier 2 Bin 2 and California SULEV emissions levels (i.e., NMHC + NOx levels of 0.03 grams/mile). To check this assertion we accessed the Agency’s model year 2011 vehicle emissions certification database and found that there are at least 19 vehicle model configurations already in production that have been designed to meet either the Tier 2 Bin 2 or California SULEV with almost 50% over compliance while operating on federal Tier 2 sulfur compliant certification gasoline.**

This suggests that the automakers already are successfully designing products taking into consideration today’s gasoline sulfur levels. We are not aware of any published studies or anecdotal evidence that suggests that any of these vehicle models are experiencing issues while operating on gasoline that meets current federal sulfur requirements (e.g., 30 ppm refinery gate average/ 95 ppm retail max).

**The impact of higher levels of ethanol in gasoline on NOx emissions - AAM’s argument that lower levels of sulfur in gasoline are needed to counteract the NOx emissions impacts associated with expected higher future levels of ethanol in gasoline is unsupported. It ignores the dilution effect associated with adding more ethanol to gasoline. We know of no publicly available study that has quantified the emissions effects on modern vehicles associated with the systematic variation of both the sulfur and the ethanol content of gasoline.**

**Sulfur irreversibility - AAM argues that the effects of higher sulfur excursions on the emissions performance of modern technology vehicles are reversible with a return to lower sulfur gasoline only under driving conditions that are more aggressive than those represented by the EPA Federal Test Procedure (FTP) driving cycle. Recent investigations, including the Ball et al PZEV study prominently figured in the AAM White Paper, appear to support this observation.** However, AAM’s suggestion that the opportunity for high speed/high load driving is of limited availability to the inhabitants of ozone non-attainment areas (i.e., urban locations) is unsubstantiated.

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8 See page 3 of the AAM White Paper: “EPA should consider that many consumers may drive in a manner not conducive to catalyst burn off...”
A study of driving patterns in Baltimore, MD in the early 1990s observed speeds ranging up to 95 mph, vehicle accelerations of up to 15 mph/second and maximum specific power events of 558 mph²/sec that were significantly higher than the comparable values for the relatively mild EPA FTP driving cycle (56.7 mph, 3.3 mph/sec, and 192 mph²/sec, respectively). About 18% of the sample of the measured vehicle speed/acceleration events in this Baltimore study fell outside of the bounds of those represented by (i.e., were more aggressive than) the EPA FTP. In addition, data from the US Federal Highway Administration show that nearly 46% of the average daily vehicle miles of travel at posted speeds of 60 mph or higher occurs on urban roads. Clearly, a not insubstantial fraction of urban dwellers engage in aggressive driving. When considered in conjunction with the decades-old trends of rising posted speed limits and increasing vehicle performance, then arguably the conditions are in place and available to allow urban consumers to continue to engage in the type of aggressive driving deemed necessary to reverse the emissions effects of higher sulfur gasoline in advanced technology vehicles.

AAM contends that “[t]he reversibility of the [sulfur] poisoning, especially over time, in a vehicle chronically exposed to higher sulfur retail gasoline, is an important issue.” We are not aware of any studies, especially of vehicles with emission approaching those being considered for Tier 3, which have addressed long term effects associated with sulfur reversibility. The studies in the literature which have examined the reversibility of sulfur impacts on emissions have only measured short term effects, and it is not clear that one batch of higher sulfur fuel will increase emissions for the vehicle’s entire lifetime. If AAM believes that the reversibility of sulfur poisoning over the lifetime of a Tier 3-like vehicle is an important issue, then it should provide data which clearly demonstrates the magnitude of the long term emissions effect. It also should provide data on the proportion of the vehicle fleet that is “chronically exposed to higher sulfur retail gasoline” to support its contention in this regard. We are not aware of any published or publicly available data on either topic.

**Sulfur oxide emissions** - The AAM letter claims that a 10 ppm sulfur cap would “…immediately reduce emissions of vehicle sulfur oxides...by an estimated 15,626 tons per year.” To focus on the sulfur oxide reduction benefits of a 10 ppm sulfur cap is misleading and irrelevant when taken out of context. EPA’s national emissions inventory data show that the contribution of the on-road mobile sources to the total SO₂ emissions inventory is dwarfed by other sources (e.g.,

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11 See, for example, a table of “Maximum Posted Speed Limits,” published by the Insurance Institute for Highway Safety, Highway Loss Data Institute ([http://www.iihs.org/laws/SpeedLimits.aspx](http://www.iihs.org/laws/SpeedLimits.aspx)) which shows that as of today, ~35 states had posted speed limits of 65 mph or higher on their urban interstate highways.

in 2008 the contribution of electric utilities to the nationwide SO\textsubscript{2} emissions inventory was \textbf{183 times larger} than that of the on-road mobile source sector), leading one to question the cost-effectiveness of gasoline sulfur reduction for this purpose.\textsuperscript{13}

\textbf{According to AAM, an unspecified reduction in gasoline vapor pressure and an unspecified increase in octane number will be needed.}

AAM supports a gasoline vapor pressure reduction by stating that it will decrease evaporative emissions. However, AAM does not acknowledge, as it does for sulfur, that the fuel and the vehicle need to work as a system, and that on board vehicle controls could also achieve this goal, perhaps at a lower cost.

AAM also states that increases in the octane number of gasoline are necessary to help the automakers to design vehicles that achieve higher fuel economy. This is yet another unsubstantiated argument. For decades, the petroleum industry has been offering the motoring public a choice to purchase gasoline with higher octane numbers. That gasoline is generally called “premium unleaded” and it is available for sale at most retail gasoline outlets.

It is noteworthy that the AAM letter appears to be inconsistent with the AAM statement on page 7 of Appendix 2 of the White Paper which reads “The Alliance believes it is acceptable for premium gasoline to be defined as having a minimum 91 octane ((R+M)/2).”

AAM recognizes the high octane properties of ethanol, notes the prospect for greater volumes of ethanol to be blended into the gasoline pool to meet the RFS mandates, and argues that refiners should not be allowed to reduce the octane number of hydrocarbon base stocks used for blending with ethanol. Such a prohibition would significantly reduce refining flexibility with consequential impacts on product supply and costs. From the refiner’s perspective, the ability to offer blendstocks for oxygenate blending (CBOB & RBOB) provides for a more cost effective final product when ethanol is added. Furthermore, requiring the vast majority of vehicles to use gasoline with an octane rating higher than for which they are designed is a misuse of resources.

It also is important to note that consideration for changes to both vapor pressure and octane number cannot occur in a vacuum or independently of one another. It needs to be based on an evaluation of all impacts on refining and distribution. (For instance, to reduce vapor pressure, refiners would likely need to curtail the amount of butane blended into the gasoline pool, but butane is a high octane blendstock, so this strategy cannot be considered alone).

Furthermore, any analysis of increased octane should include the entire pathway (well-to-wheels). Studies by MathPro and JCAP II (which we shared with your staff on

\textsuperscript{13} US EPA, 2008 National Emissions Inventory, \url{http://www.epa.gov/cgi-bin/broker?_service=data&_debug=0&_program=dataprog.national_1.sas&polchoice=SO2}
March 17, 2011) have shown that refinery greenhouse gases will increase with refinery operational changes to increase octane. Any benefits from vehicle engine efficiency need to be substantial to overcome the refinery GHG increases.

**AAM underestimates the refining costs of lowering gasoline sulfur and vapor pressure**

The cost estimates (prepared by MathPro) which appear in an appendix to the AAM White Paper are based on the use of linear programming (LP) for four “notional” refineries to represent all of PADDs 1, 2 and 3 and California. LP modeling with notional refineries treats the entire PADD as one large refinery, and implies that adding required refining capacity can occur at the same rate and economies of scale across all refineries within the PADD. This results in over optimization and underestimation of compliance costs by a factor of 4 relative to a similar study performed by Baker & O’Brien under API sponsorship. (See the table below.)

The Baker & O’Brien study examined the refining costs associated with lowering sulfur and vapor pressure in gasoline to levels in several scenarios comparable to those under consideration for Tier 3 and one of which also is comparable, albeit less severe, to the case MathPro modeled.

In contrast to the MathPro approach, the Baker & O’Brien report includes a refinery-by-refinery analysis and is based on a mass balanced model that accounts for all hydro-carbon molecules. The refinery-by-refinery analysis takes into account characteristics unique to specific refineries and considers each refinery’s compliance option and required investments. Unlike the limited geographic scope used by MathPro, the Baker & O’Brien modeling approach includes refineries in all 5 PADDs.

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<th>Total Compliance Costs Comparison ($2009 billion)</th>
<th>Refinery Investment</th>
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<td>MathPro</td>
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<tr>
<td>Baker &amp; O’Brien</td>
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As mentioned above, researchers at Baker & O’Brien have evaluated several Tier 3 scenarios and have concluded that the costs of reducing gasoline sulfur and volatility are significant:

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14 The refinery cost study relied upon by AAM was updated in late October 2011 under the sponsorship of the International Council for Clean Transportation. We have obtained a copy of this updated effort and will likely offer detailed comments after completing an evaluation of it. However, while the magnitude of the results from this revised study may have changed, the underlying methodology did not, and therein lies our major concern.

- **7% to 14% reduction in gasoline supply:** The new standard will prevent refiners from being able to utilize clean, higher vapor pressure gasoline, and reduce the amount of fuel they can produce.

- **1% to 2.3% increase in refinery CO2 emissions:** More energy intensive refining processes will be needed to meet the new fuel specifications, resulting in more refinery greenhouse gas emissions.

- **Significantly increased costs:** Up-front capital costs are projected between $10 billion and $17 billion. Recurring operating costs, including capital charge, to the refining industry are projected between $5 billion and $13 billion annually.

- **Gasoline manufacturing cost impacts of 12 cents to 25 cents per gallon:** Higher manufacturing costs could negatively impact the marketplace.

- **Between 4 and 7 refinery closures:** When coupled with EPA initiatives to reduce greenhouse gas emissions from refineries and other EPA regulatory programs, U.S. refineries will be put at a competitive disadvantage, potentially resulting in more refinery closures.