Proposed Diesel Sulfur Regulations and Emission Benefits of Current Regulations

Scientific Peer Review

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Introduction

This is a review for the California Air Resources Board proposed changes and additions to regulations for the California reformulated diesel fuel. This review is prepared under Interagency Agreement #98-004 between the University of California and the California Environmental Protection Agency.

This review covers the document titled "*Proposed Amendments to the California Diesel Fuel Regulations, Staff Report: Initial Statement of R*easons" dated June 6, 2003. In addition, I reviewed some of the additional references provided by the Air Resources Board, as well as the comment and reviews of the Western States Petroleum Association, Prof. Robert Sawyer of UC Berkeley, and Prof. Lawrence Caretto of California State University, Northridge.

Proposed Revisions

The Staff of the Air Resources Board is proposing amendments to the California diesel fuel regulations. These major changes proposed would:

1. Reduce the sulfur content limit from 500 ppmw to 15 ppmw for diesel fuel sold in California for use in on-road and off-road motor vehicles staring in mid-2006.

2. Adopt an Air Toxics Control Measure to require the use of vehicular diesel fuel in all nonvehicular diesel engines.

3. Revise the sulfur specifications for diesel certification fuel used to determine whether diesel engines comply with heavy-duty diesel emission standards.

4. Revise the requirements for certification of alternative diesel formulations to require 15 ppmw sulfur limits for candidate and reference fuels.

5. Establish additional requirements for certification of alternative diesel formulations to ensure that the fuels produced under the alternative formulation has comparable emissions performance to the candidate fuel.

6. Adopt new specifications for equivalency to the aromatic hydrocarbon limit for diesel fuel to provide another compliance option.

7. Adopt standards for diesel fuel lubricity.

8. Make other changes, including improvements to the sulfur test method and a revision of the definition of diesel fuel, to ensure that regulation works effectively.

Review of *Proposed Amendments to the California Diesel Fuel Regulations, Staff Report: Initial Statement of Reasons*, dated June 6, 2003.

Specific Comments relating to proposed amendments:

1. Reduce the sulfur content limit from 500 ppmw to 15 ppmw for diesel fuel sold in California for use in on-road and off-road motor vehicles staring in mid-2006.

The U.S. Environmental Protection Agency will impose a 15 ppmw sulfur limit on diesel fuel in 2006. The main reason for this standard is to protect the emissions controls that are most likely to be used for diesel engines to meet the 2007-2010 heavy duty emission standards and the 2007 light duty emission standards. These systems will be catalyzed diesel particle filter, NOx after-treatment, and other advanced after-treatments.

The need for low sulfur fuel for these systems is reviewed in the staff report and is reasonable. The effect of higher sulfur levels on these systems is shown to be detrimental. In additional, there is a direct effect on particle emissions due to reduced sulfate and other sulfur derived emissions, such as sulfur dioxide. There is considerable evidence both from the U.S. EPA and California that lower sulfur levels are needed, and that setting the level at 15 ppm, the same as the federal standard, is appropriate.

The alternative of even lower sulfur stands was addressed. For the exhaust technologies, lower sulfur levels are not cost-effective, but newer treatment methods may require even lower sulfur levels. A zero sulfur level diesel fuel may be desirable in the future, and the ARB should continue to consider this as a future alternative.

2. Adopt an Air Toxics Control Measure to require the use of vehicular diesel fuel in all nonvehicular diesel engines.

The rationale for adopting this standard for both on-road and off-road vehicles is sound. Without new regulations, the EPA 15 ppmw standard will apply, but only to on-road diesel fuel use. The SCAQMD 15 ppmw standard applies to on-road, off-road, and stationary engines, but it is limited in that the standard is not state-wide, which is necessary if for retrofitting older engines as well as new engines requiring advanced exhaust treatment. Off-road diesel PM emissions are larger than on-road emissions, so including these engines is important.

The amendment would require the same diesel fuel to be burned in nonvehicular engines. This should produce benefits in reduced emissions from stationary engines. As noted in the report, most diesel engines in California already use the same fuel since the state has

a single fuel distribution system. This change would ensure that the benefits obtained from the lower sulfur fuels are maintained.

As noted in the report, U.S. EPA regulations are needed to reduce emissions from locomotives, aircraft, heavy-duty vehicles used in interstate commerce, and other sources that are preempted from state control. The ARB should continue to work with the EPA and others to develop control measures for these engines.

3. Revise the sulfur specifications for diesel certification fuel used to determine whether diesel engines comply with heavy-duty diesel emission standards.

It makes sense to have a certification fuel with similar properties to the fuels that will be used in heavy-duty diesel engines. The lower sulfur levels in the certifications fuels will also allow the use of both NOx and PM aftertreatment devices.

4. Revise the requirements for certification of alternative diesel formulations to require 15 ppmw sulfur limits for candidate and reference fuels.

5. Establish additional requirements for certification of alternative diesel formulations to ensure that the fuels produced under the alternative formulation has comparable emissions performance to the candidate fuel.

Consistency with the sulfur standard in Section 2281.

Having the same 15 ppmw sulfur limit for both the reference and candidate fuels is appropriate.

Emission equivalency of candidate fuels to in-use fuels

This would ensure that future candidate fuels tested in the laboratory are fully characterized. The action is appropriate.

Emission equivalency of candidate fuels to reference fuels.

This would tighten the tolerances allowed for each pollutant. The new values are based on 16 fuels tested in the same laboratory, and are reasonable.

Elimination of the sulfate credit

The elimination of the sulfate credit is reasonable, as the 15ppmw limit makes difference between the sulfur levels in the reference and candidate fuels insignificant.

6. Adopt new specifications for equivalency to the aromatic hydrocarbon limit for diesel fuel to provide another compliance option.

The adoption of alternative compliance options that provides equivalent environmental benefits to the 10% aromatics hydrocarbon limit is a good proposal. Allowing different formulations that meet and retain equivalent environmental benefits is reasonable, as the emissions from fuels are key factors here, not the composition of the fuel.

Regarding the new fuel specifications for equivalency to the aromatic hydrocarbon limit, these comments are directed at Appendix D (*Staff Review of the Emission Benefits of California's Diesel Fuel Program*, with a date of March, 2003), Appendix E (*Staff Analysis of Future Emission Benefits of California's Diesel Fuel Program*), and Appendix.F (*Effects of Changes in Diesel Fuel Properties on Emissions*).

As noted by the other reviewers, there are considerable problems in determining the effects of individual fuel parameters when these parameters are interrelated. I agree with the conclusions of Profs. Sawyer and Caretto that the interdependence of fuel parameters such as aromatics, specific gravity, and Cetane number make it difficult to quantify the effect of varying a single property.

This being said, there is considerable evidence from the 31 studies reviewed that emissions of NOx and PM are reduced when sulfur and aromatics are limited. As noted in the report, the HDEWG model may have limited applicability, since the data is from one engine operating in one configuration, and no PM measurements were made. These studies used a variety of fuels and engines. However, the vast majority of the engines are 1996 model year or earlier. The addition of new engines and engines retrofitted with advanced exhaust treatment systems is another factor that has a large uncertainty that is not clearly covered.

7. Adopt standards for diesel fuel lubricity

Lower sulfur levels will reduce the lubricity of diesel fuel as a result of severe hydrotreating refiners are expected to use to meet the new standards.

There are currently no government or industry standards in the U.S. controlling diesel fuel lubricity. In California, there is a voluntary minimum lubricity level of a Scuffing Load Ball-on-Cylinder- Lubricity Evaluator (SLBCOCLE) scuffing load of 3,000 grams or higher. The U.S. EPA allows industry and the market to address the lubricity issue in the most economical manner. The ASTM has not been able to agree on a lubricity standard nor a testing method. However, other agencies in Canada and Europe have adopted lubricity standards.

While it appears that lubricity additives will be used by refiners, the nature of the additive is not specified. If the ARB wants to specify a lubricity standard, they might want to also ban certain types of additives, such as acidic additives that can form harmful salts.

Change in the fuel specifications can produce concerns that engine or engine parts failures are due to the different fuels, with accompanying costs due to legal actions. The adoption of a standard may reduce these concerns, but it is not clear that this is an emissions issue. In the report, there is a discussion of the pump wear data, and results are presented in Appendix G. There is a statement on page 73 that " fuels with insufficient lubricity contribute to excessive wear that results in reduced equipment life and performance. Excessive wear in these systems is also expected to increase emissions due to compromised pump performance." While that is a reasonable conclusion to reach, there are no references or test data given to support that statement.

In light of the lack of U.S. standards, it might be better to allow the industry to continue with the current practice, and wait until a consensus is reached by ASTM, as suggested as an alternative in the staff report. This would also bring the California regulations more into alignment with the U.S. standards.

8. Make other changes, including improvements to the sulfur test method and a revision of the definition of diesel fuel, to ensure that regulation works effectively.

Test method for sulfur

The staff proposes to change the method for determining the sulfur content of diesel fuel. Current regulations require that sulfur in diesel fuel be determined by ASTM D2622-94 (x-ray spectrometry). As the current method doesn't not have the sensitivity or precision needed to measure sulfur at levels of 15 ppmw, another method is required. The method proposed (ultraviolet fluorescence, D5453-93) is reasonable, and it has been used in similar fuels with lower sulfur levels.

Definition of diesel fuel

The definition of a diesel fuel as any predominantly hydrocarbon liquid fuel without specifying or clarifying what "predominantly" means can be a problem for diesel fuels that might contain significant amounts of a non-hydrocarbon, such as oxygenated species. However, if oxygenated fuels are considered, then additional problems with other issues such as water quality (some oxygenated compounds are soluble in water) and the cost of producing these fuels would change.

Other comments:

In Section V, Health Benefits Of Diesel Emissions Reductions (page 27), the complexity of the chemical composition is mentioned, but there is little discussion of the effects of particle size on health, especially the role of ultrafine particles. While 94% of the mass of diesel particles are contained in particles smaller than 2.5 microns, diesel particles produced by modern engines are better characterized by sizes in the hundreds of nanometers and smaller. Reducing the sulfur content should reduce the formation of particles formed from the condensation of sulfuric acid, but their role in the health effects is unclear.

Potential Cancer Risk

The discussion on page 25 assumes that a reduction in diesel PM will lead to a proportional reduction in cancer risk. Some caution should be taken here since the changes proposed here will certainly not only change the mass of diesel PM, but will probably change the chemical composition of the resulting particles, and it is not clear that all of the possible carcinogenic compounds in the exhaust will be reduced by the same fraction.

Overall costs of the proposed amendments

The ARB staff estimates that the costs of reducing the sulfur content of diesel fuel and adding required lubricity additives as between 2 and 4 cents per gallon of diesel. It is noted, but not emphasized, that most of the costs to refiners would occur as a result of adopted U.S. EPA and SCAQMD regulations. The real cost of the amendments is thus the cost of extending the regulations to the 25% of the total diesel fuel consumed by off-road diesel vehicles outside the SCAQMD. Staff estimates that as much as 90% of the cost can be attributed to the other regulations. The real cost of the proposed changes thus appears to be 0.2 to 0.4 cents per gallon of diesel fuel.

Water Quality

The assessment in Appendix K concludes that there would be no impacts on ground water associated with proposed low-sulfur diesel fuel. This is correct for the hydrocarbon portion of the fuel. However, the proposed redefining of “diesel fuel” to be any mixture of primarily liquid hydrocarbons raises the issue of the impact of non-hydrocarbon compounds, such as oxygenated compounds, that could be more water soluble. The effects of oxygenates in gasoline has been studied by the ARB previously, and could be cited here. The report also states that alternative diesel fuels generally contain more than tract amounts of oxygenated fuel constituents or are emulsified with water.

Diesel Engine Lubrication Oils

As the emissions from burning diesel fuel decrease, the fraction of the emissions that arise from lubricating oils can increase. There are two ongoing research efforts that are examining the impact of lubricating oils and oil additives on emissions and emission control devices. Preliminary results from Advanced Petroleum-Based Fuels Program Diesel Emission Control- Sulfur Effects (APBF – DECSE) suggest that some oil formulations produce higher levels of sulfur emissions. These results are an indication that staff needs to follow and support this and related work, especially in the effects of oils and oil additives on advanced aftertreatment technologies.