November 29, 1999

To: Mr. Michael P. Kenny
Executive Officer
California Air Resources Board
P.O. Box 2815
Sacramento, CA 95812

From: Catherine P. Koshland, Wood-Calvert Professor in Engineering, Professor of Energy and Resources and Environmental Health Sciences, University of California, Berkeley

Re: Interagency agreement 98-004
Scientific Peer Review of Staff Report entitled "Proposed regulations for California Phase 3 Reformulated Gasoline (CaRFG3) - Staff Report"

Introduction

The document "Proposed regulations for California Phase 3 Reformulated Gasoline (CaRFG3) - Staff Report" supporting the proposed changes in California Reformulated Gasoline standards, has been reviewed by Professor Catherine Koshland, PI (UC Berkeley), Dr. Donald Lucas (LBNL), and Dean Laurence Caretto (Cal State University, Northridge). Each reviewer is submitting an independent report to the CARB. The reviewers have discussed in general the issues, but have not collaborated in the development of specific reviews. The time period in which to develop the reviews has been less than one month.

The objectives of the reviews are to provide a scientific peer review of the staff report including revisions to the ARB Predictive Model, and specifications for California Phase Three Reformulated gasoline. The review that follows is that of Prof. Catherine Koshland. Reviews by Dr. Donald Lucas, and Dean Laurence Caretto will be transmitted under separate cover.

The staff report documents the changes proposed. In response to Executive Order D-5-99, to Senate Bill 989 (Sher), and to Senate Bill 529 (Bowen), the staff has proposed amendments to the regulations for CaRFG2. The staff's objectives in developing the CaRFG3 regulations were to "provide flexibility to refiners to make or import CaRFG3 without MTBE, to preserve significant emissions benefits realized from the current

CaRFG 2 regulations, and to obtain additional emissions reductions where technically feasible and economically reasonable." The staff report provides a descriptive rationale for the adjustments made to both phase out the oxygenate MTBE, and to take advantage of advances since 1994 in the understanding of the impacts of fuel formulation changes on air quality through effects on both evaporative and tailpipe emissions. Since significant reductions of hydrocarbons, NOx, CO, sulfur and toxics emitted from vehicles have been observed since CaRFG2 was implemented in 1996 (see Table I-2 plus other studies). Maintaining these improvements in air quality is a central goal of these proposed changes. Specifically, the staff lists six objectives

1. To remove MTBE from California gasoline
2. Maintain the significant emissions benefits obtained from the current CaRFG2 program
3. Provide additional flexibility to California refiners to facilitate the removal of MTBE.
4. Identify additional opportunities for further emissions reductions that are cost-effective.
5. Be sensitive to the increasing need to import gasoline to meet the increasing demand for gasoline in California
6. Provide flexibility where possible, without sacrificing emissions benefits, to facilitate the expected significant use of ethanol in California gasoline.

The proposed amendments are summarized briefly below:

1. Prohibition of the use of MTBE by Dec. 31, 2002
2. Reduce the sulfur limits.
3. Reduce the benzene limits.
4. Increase the flat, averaging and cap limits for T50 and T90.
5. Increase the aromatic hydrocarbon cap (while maintaining the CarFG2 flat and averaging limits)
6. Permit use of variable RVP, and add an evaporative hydrocarbon emissions element to the predictive model
7. Amend the predictive model to allow a credit for relative reactivity of CO emissions to offset changes in either evaporative or exhaust hydrocarbon emissions during the RVP season.
8. Changes in the oxygen cap up to 3.7 weight percent oxygen to allow for gasoline that contains no more than 10 percent ethanol by volume.
9. Updates to the predictive Model to reflect changes in the vehicle fleet, and changes in the newer vehicles response to change in fuel properties.
10. Addition of a new specification for driveability index to preserve vehicle driveability and compliance with LEV II standards.
11. Streamlining of some CARBOB (California reformulated gasoline blendstock for oxygenate blending) requirements
12. In 2003, remove October from the wintertime oxygen season to eliminated overlap with the RVP season.

Overall evaluation

The document provides both a comprehensive rationale as well as specific information on the proposed changes. It is responsive to the Executive Order and to the applicable Senate Bills. However, given the short time to develop these changes, it may be prudent for the Board to consider the need for balance between timely regulations, and good science. Creating a means within the regulations for adjustments based on improved understanding of the science would ensure a timely implementation process as well as an opportunity for peer review in those areas still under development.

Comments on specific issues

The CaRFG3 specifications have been developed with an eye towards increasing the flexibility for refiners. This emphasis does raise some concerns about the ease with which automobile manufacturers will be able to design for excellent emissions performance and fuel economy with the wide range of fuel characteristics that the vehicles may encounter in use. Clearly, the vehicle manufacturers would like to design to a single fuel specification; however, fuels have always been created to respond to environmental conditions such as high altitude. Clearly manufacturers can find ways to design to a range of fuels. At the same time, flexibility for refiners must be balanced with vehicle performance objectives.

Two issues in particular affect the auto manufacturers: reduced sulfur content and variable RVP. The reduced sulfur content is an advantage to manufacturers as it permits more efficient performance of the emissions control systems. The variable RVP presents challenges to designers but creates flexibility for refiners, and offsets some of the restrictions imposed by reduced sulfur levels. These two provisions provide some relief to each stakeholder while ensuring that the public and environmental health objectives of improved air quality are met.

It is instructive to evaluate the fuels with both the CaRFG2 Predictive Model and the proposed CaRFG3 Predictive model. Both models suggest that there is room for improved performance without undue hardship for refiners. There is no question that including the evaporative emissions in the model, and developing the relations for Tech 5, the most advanced vehicles, makes sense in light of developments in our understanding of evaporative emissions impact on ozone and toxics exposures. However, the model has not been subject to extensive peer review, nor has the key component EMFAC 2000 (recently renamed from EMFAC 99) had sufficient scrutiny. Again, good science, and timely regulatory action must be balanced.

The document as a whole lacks any information on uncertainty or an indication of statistical confidence (such as reporting standard deviations or 95% confidence intervals). While from a legal and regulatory dimension, the apparent lack of ambiguity is attractive, from a scientific perspective, it means a lack of context and hence could diminish confidence in some of the recommendations. One would hope that someday, the essential ambiguities that can exist in science may be accommodated in our contentious legal rule making process.

Comments on specific sections

Page x, Executive summary, section J. 6, Added evaporative emissions element to the predictive model

The text mentions a "new ability to control RVP" It is not clear what staff intends in this phrase: does it imply a technological advance, or is it merely a statement about the new flexibility for refiners by allowing a variable RVP during the RVP season?

Page xv, Executive summary, section L, 1, Emissions inventory EMFAC 2000.

There are concerns about the use of the EMFAC 2000 emissions inventory in the CaREG3 predictive model. The inventory has just been released in draft form, and has yet to undergo extensive peer review. Changes in this inventory may affect predictions in proposed regulations. It is critical that the Board creates some flexibility in adopting the regulations so they can be adjusted to reflect any corrections or changes in the inventory after it has received comment and review.

Page 17, Chapter II. Gasoline Consumption and Properties of CaRFG2

It is apparent that refiners can produce a cleaner gasoline with a margin of "safety" for compliance. It is essential that as regulations are changed, that the gasoline produced maintains its "cleaner qualities", especially with the provisions for increased flexibility and variable RVP. The question here is whether 64 samples is enough to estimate the compliance margin (Table II-4). Since no range of values is given, one is unable to estimate the uncertainty associated with the compliance margin. Since these values are being used to determine estimated in use fuel properties, and the future in use fuel, care needs to be taken in determining the compliance margin. Are compliance margins under CaRFG3 presumed to be the same absolute value as those observed, or are they expected to be scaled so that percentage compliance margin would be the same?

Page 18-19, Chapter II. Gasoline Consumption and Properties of CaRFG2

The driveability index appears to be the one area where concerns of vehicle manufacturers are addressed. The section in which this is discussed is not very satisfactory. It may be helpful to include the information on page 26 in Chapter III in Chapter II. The staff does not develop a clear argument for their choice of a DI = 1225, with an oxygen correction. They state that vehicle manufacturers prefer a DI below 1200 to 1250 (presumably these values include oxygen – if not the text should so indicate) but don't indicate why; later they state that the auto manufacturers want a DI of 1200 with oxygen correction to ensure good driveability. Nor do they indicate why ASTM adopted a standard of 1250 without the correction for oxygen. Similarly, they state that current California gasoline has mean DIs of about 1160 with oxygen, and 1120 without, considerably lower than the standards or the recommended DI = 1225. Two questions arise here.

1. The DI is defined as 1.5*T10 + 3.0*T50 + T90 + 20* oxygen weight percent; what then is the oxygen correction referred to on the bottom of page 19 if the definition of DI includes oxygen?
2. Without a standard deviation around the mean of the samples in Table II-6, and in Table 11-7, it is difficult to know the significance of the maximum DIs listed. This is important for assessing the choice of DI = 1225. Why not 1215 or 1220?

Page 26, Chapter III Proposed CaRFG3 Regulations

The staff is to be commended for taking advantage of the considerable data and information generated on Federal Tier I and Ca LEVs since the 1991-94 timeframe, and proposing changes to the predictive model. The main issue here is the "untestedness" of the EMFAC 2000 Motor Vehicle Emissions Inventory. However, review of that should be simultaneous with the development of the regulations, with provisions for adjustments to the regulations included by the Board to assure that there is both good science and timely development of the regulations.

Page 26, Chapter III Proposed CaRFG3 Regulations, Section 1. Updates for the CaRFG3 Predictive Model

Adding the data for Tech 3 and Tech 4 model groups, and creating the Tech 5 model group is an excellent development in creating a revised predictive model. As has been shown in studies by Harley and co-workers, the contributions to reduced emissions from fleet turnover, and from CaRFG2 are difficult to separate – it is clear that both are important contributors. Not accounting for the advances in vehicle technology would be a serious omission in the Predictive model.

Page 27, Chapter III Proposed CaRFG3 Regulations, Section 2 Additions to the CaRFG3 Predictive Model

Because there was no flexibility in RVP under CaRFG2, there was no need to include an evaporative emissions model. On page 27, the text states "With the ability to vary RVP, refiners now can offset exhaust hydrocarbon emissions with evaporative… emissions" I assume this means that increase in one would be offset by decreases in the other but that is not explicit in the language, and should be

Page 28, Recognition of CO credit.

Recent work on the role of CO in the formation of ozone has indicated a more significant role for CO emissions than has previously been recognized. Thus staff has proposed that CO reductions should be credited to exhaust and evaporative emissios based on CO's relative reactivity. Some stakeholders (Whitten) have expressed the view that this contribution is still underestimated, and argue that a higher value for the MIR used in the modeling would be more appropriate. Based on a review of his argument and a counter argument, I would concur at this stage that the current MIR value is the more appropriate. The latter has received extensive peer review, is the value currently in use in California, and reflects not only peak ozone simulations but as important, the population and spatial exposure metrics. From a public health perspective, it is not the peak ozone value but the population exposure metric that is most important. I am also concerned that

an overemphasis on CO reactivity may overshadow the issues related to NOx emissions in California.

Page 29-35, G. Amendments Pertaining to the Treatment of "CARBOB"

This section clearly needs more work (as the staff indicates) and development of these provisions must ensure that there are safeguards and compliance measures in place if greater flexibility is to be offered.

On page 31, Section 2, the staff suggests that a system-wide set of pertinent specifications for denatured ethanol intended for use as an additive in California gasoline be adopted. I strongly concur with this since ethanol is often denatured with gasoline, a process that without appropriate standards could compromise the actual in-use fuel.

On page 35, Section 5, the staff raises the issue of commingling of non-oxygenated gasoline with gasoline oxygenated with ethanol, a situation that can lead to a 1 psi increase in RVP. This issue is a serious one; having blenders affirmatively demonstrate that a blend does not exceed the RVP standard is an important regulation. Some research should be devoted to the issue of commingling in a motor vehicle fuel tank for its impact on emissions performance although the regulation will not apply to individual vehicle fuel tanks.

Page 40, Chapter IV, Other issues considered A. Relief from the Federal RFG Oxygen requirement

As I have stated previously in this review, the impact on NOx emissions and the subsequent impact on ozone, and PM10 and PM2.5 of providing flexibility in the oxygen content requirement is insufficiently argued in the document as a whole. The value of zero-oxygen fuels is succinctly presented in this section but I think should also be emphasized in the executive summary as well. This argument is also stated strongly in Appendix E, the letter to Ms Margo T. Oge on Sept. 20, 1999. Question 4.

Page 50, Chapter V, Effects of proposed changes on emissions, Section 1 Selection of fuel properties

Proposed RFG specifications included an increase in the flat limits for T50 and T90. Since it is stated in several places in the text, that lowering T50 and T90 reduces HC emissions, a rationale for increasing these limits needs to be made more explicit, i.e. that by slightly increasing T90 and T50, some of the overall production volume lost by removal of MTBE may be compensated. Is it possible to add a future adjustment, that if production capacity is increased in California, that the values for T90 in particular might be reduced?

Appendix G, page G-2. There is a typo on the tables – I believe Table 2 should read Summary of percent CO Increases associated with a one percent <u>decrease</u> in fuel oxygen from selected studies. On page G-4, the text states that "reducing the oxygen content of gasoline will result in an increase in CO and HC emissions." This statement directly contradicts the letter on Sept. 20 that states that the ability to reduce NOx and evaporative HC emission or maintain the existing emissions benefits is greater without oxygen. I assume that the G-4 comment refers to tailpipe HC or CO emissions, and also assumes

that no other change to the gasoline would occur – an unlikely scenario at best since a gasoline that simply removes the oxygenate would not meet all the standards associated with CaRFG. I caution the staff in making blanket statements of this nature without qualifying exactly what is meant.

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Recommendations

Given the tight timeframe for developing and reviewing the regulations, the Board may wish to consider adopting the recommendations but with provisions for adjustments to the regulations based on revisions of draft documents such as EMFAC99.

It is strongly recommended that the State persist in its efforts to obtain waivers for the oxygenate provisions.

It is recommended that staff devote more text to the advantages in California of reduced NOx emissions for both ozone control and secondary aerosol formation, and the benefits that might be accrued in reducing NOx if the oxygenate requirement is eliminated.

It is recommended that the reduction in sulfur content be supported. One of the key tensions in developing these amendments is the need to provide flexibility to refiners while still developing predictable fuel specifications for which the auto manufacturers can reliably design. Reducing sulfur reduces HC, NOx and toxics.