Proposed Determination Pursuant to Health and Safety Code Section 43830(g) of the Ozone Forming Potential of Elevated RVP Gasoline Containing 10 Percent Ethanol

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Air Resources Board
P.O. Box 2815
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California Environmental Protection Agency
California Air Resources Board

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I. EXECUTIVE SUMMARY AND OVERVIEW

This report presents the Air Resources Board (ARB) staff's assessment of the ozone forming potential of elevated Reid vapor pressure (RVP) gasoline containing 10 percent ethanol. The report also contains the staff's recommendation that the Air Resources Board find that California reformulated gasoline containing 10 percent ethanol results in an increased ozone forming potential if the gasoline is exempt from the ARB's standard for RVP. This finding would eliminate the conditional RVP exemption in Health and Safety Code (HSC) section 43830(g) for gasoline containing 10 percent ethanol.

A. The ARB's Summertime RVP Standard and the Statutory Exemption for Gasoline Containing 10 Percent Ethanol

RVP is a measure of gasoline volatility. Gasoline with a higher RVP is more volatile than gasoline with a lower RVP, and thus has a greater propensity to evaporate. The California reformulated gasoline (CaRFG) regulations limit the RVP of summertime gasoline to 7.0 pounds per square inch (psi) in order to control evaporative emissions of hydrocarbons. HSC section 43830(g), enacted in 1991, exempts gasoline blends containing 10 volume percent ethanol from the RVP standard. But the statute makes the exemption inapplicable if the ARB finds that such blends result in increased ozone forming potential, excluding consideration of oxides of nitrogen (NOx), compared to gasoline that complies with all of the CaRFG standards. It further provides that the ARB's finding must be based on independently verifiable motor vehicle emission test data from a representative vehicle fleet.

Adding ethanol to gasoline introduces oxygen. Adding ethanol at 5 to 10 percent by volume also increases the RVP of the gasoline blend by about 1 psi, and thus increases evaporative emissions. Until now, the oxygen cap limit of 2.7 weight percent (wt.%)[1] in the CaRFG regulations has restricted the amount of ethanol blended into gasoline to about 7.7 percent by volume, thus precluding gasoline containing ethanol from qualifying for the exemption for 10 volume percent ethanol blends. However, the Board is considering a staff proposal to increase the oxygen cap to 3.5 wt.% in order to give refiners more flexibility in formulating gasoline. This would permit the use of 10 percent ethanol in gasoline which, in turn, would allow refiners to market gasoline that exceeds the 7.0 psi RVP limit. The Board accordingly continued consideration of the staff's proposal to raise the oxygen content cap to its December 10-11, 1998 meeting so that the Board could first consider whether to make the finding that would remove the RVP exemption pursuant to HSC section 43830(g).

[1] The amount of an *oxygenate* such as ethanol or MTBE in gasoline is expressed as percent by volume. The amount of *oxygen* in gasoline is expressed as percent by weight (wt%). In this report, the amount of oxygenate in gasoline is referred to simply in terms of "percent," while the amount of oxygen in gasoline is referred to as "wt.%."

B. Ozone Forming Potential as Shown by ARB's Test Program on Elevated RVP Gasoline Containing 10 Percent Ethanol

The staff's recommended finding is based on the results of a recently completed ARB test program evaluating the emission impacts of elevated RVP gasoline containing 10 percent ethanol as well as on a variety of other emission test programs and analyses. The recent ARB test program showed an overall increase of about 17 percent in ozone forming potential for the ethanol blend compared to a fully complying gasoline. The study excluded the impact of NOx but included the effect of carbon monoxide (CO) on ozone forming potential. On a per-gallon basis, this increase is about equal to the entire percent hydrocarbon emissions reduction attributed to CaRFG compared to the Phase 1 RFG that was previously sold in California.

The ARB test program used a fleet of vehicles to represent the types of vehicles most operated in California. Additionally, the results of the test program are independently verifiable and have been reviewed by an ethanol workgroup consisting of representatives from the ethanol industry, the automotive industry, the oil refining industry, the U.S. EPA, ARB staff, and other interested parties. Staff believes that, given the careful documentation of the test program and the confirmation from other test programs, the assessment of ozone forming potential meets the criteria of the HSC section 43830(g).

The ARB test program evaluated two fuels, both blended from the same base gasoline. The fully complying gasoline blend was representative of a typical in-use fuel in 1997 and met all specifications for CaRFG. This gasoline blend contained 11 percent methyl tertiary butyl ether (MTBE), which resulted in about 2 wt% oxygen content, and had an RVP of about 7.0 psi. The other gasoline blend contained 10 percent ethanol — which resulted in approximately 3.5 wt.% oxygen — and had an RVP of about 8.0 psi. Except for exceeding the current RVP and oxygen specifications, this fuel also complied with the CaRFG specifications.

Twelve vehicles covering the range of model years 1990 through 1995 were tested for exhaust emissions using the Federal Test Procedure (FTP) and a high speed, high acceleration (REPO5) test procedure. The 12 vehicles employ emissions control technologies that are representative of vehicles that account for an estimated 70 percent of the vehicle miles traveled in California in 1998. Six of the vehicles were also tested for evaporative emissions using a modified enhanced evaporative test procedure including a two-day diurnal test and a one hour hot soak test. Running loss emissions were estimated using evaporative emission models. All test samples were speciated.

Exhaust and evaporative emissions test results were combined to obtain the overall percent change in emissions using emission proportions (weight factors) generated from the motor vehicle emissions inventory. The emission results were assessed for ozone forming potential by performing a reactivity adjusted emissions analysis. The Carter maximum incremental reactivity (MIR) factors from the low-emission vehicle regulations were used to calculate the ozone forming potential of both the exhaust and evaporative emissions.

Staff evaluated the test results using two arithmetic averages (percent of the means and mean of percents methods) and a more formal statistical method which provides a comprehensive examination of the data. The arithmetic averages represent a simple assessment of the data to estimate general trends. The formal method represents a rigorous statistical evaluation of the data that provides refined estimates and allows for evaluation of statistical significance.

In assessing the percent change in ozone forming potential between the elevated RVP gasoline containing 10 percent ethanol and the complying gasoline, all three evaluation methodologies give similar results. The ozone forming potential of the ethanol blend was higher. When the ozone forming potential from CO is included along with estimates of the running loss evaporative emissions, the ozone forming potential from the gasoline blend containing ethanol is *17 percent higher* than the complying fuel using the formal method. The simpler analytical methods show increases of 16 and 19 percent. The difference in ozone forming potential is largely due to the higher RVP of the ethanol blend, which results in significantly greater evaporative hydrocarbon emissions.

The formal method of analysis shows that, for the vehicles tested, there is greater than 95 percent degree of certainty that the ozone forming potential (including CO) of the elevated RVP gasoline with ethanol is higher than the complying gasoline. Given this high level of certainty, it is extremely unlikely that additional testing of 1990 to 1995 vehicles would change the outcome of this evaluation.

The test program did not include a test procedure for determining the running loss fraction of the evaporative emissions. At the time, the capability to do such testing did not exist. Running losses were estimated using an ARB draft evaporative model. To evaluate the potential influence on the results of the test program, a sensitivity analysis was performed where the difference in running loss emissions between the two fuels was set equal to zero. The ozone forming potential of the elevated RVP ethanol gasoline, under this situation, was still found to increase by six percent compared to the fully complying gasoline. While this increase was smaller than when considering running loss emissions, the formal method of analysis still indicates with high degree of certainty that this increase is significant.

Although not required as part of the analyses specified in HSC section 43830(g), the test program demonstrated that there was a significant increase in NOx emissions on the order of 14 percent from the test fleet when it used the high RVP ethanol blend. As a result of complex chemical reactions, NOx emissions contribute to increased concentrations of ozone, particulate matter (PM_{10}), and nitrogen dioxide (NO_2). This can result in exceedances of the ambient air quality standards for these pollutants. Other air quality problems such as reduced visibility and acid deposition can also be attributed to emissions of NOx. The Board has recognized the importance of reducing NOx emissions and has implemented several control programs to reduce NOx emissions from motor vehicles. The use of ethanol in complying CaRFG does not increase NOx emissions because NOx emissions equivalency is required under the predictive model.

C. Other Confirmatory Emission Test Data and Analyses

While the ARB test program is the study that directly compares the ozone forming potential of the emissions from a elevated RVP gasoline containing 10 percent ethanol to a representative fully complying CaRFG blend, several studies have evaluated the effect of other ethanol blends on motor vehicle emissions. Even though these studies were not designed in a way that exactly compares the two fuels of most interest, and therefore are not individually sufficient to make the finding about ozone forming potential, the studies do offer strong supporting evidence on how increasing RVP and oxygen affect motor vehicle mass emissions and their associated ozone forming potential.

The large body of existing emission test data described in Chapter VI shows that gasoline blended with ethanol with an increase in RVP has higher evaporative emissions than similar gasoline with a lower RVP. A one psi increase in RVP results in significant increases in evaporative emissions of up to 40 percent. Increases in oxygen content appear to generally result in a slight decrease in exhaust hydrocarbon emissions. Based on the ARB predictive model, staff estimates that adding 10 percent ethanol (3.5 wt.% oxygen) could reduce exhaust hydrocarbon emissions by about three percent compared to a complying CaRFG with 2.0 wt.% oxygen. However, the RVP increase of 1 psi and the resulting increase in mass evaporative emissions overwhelm the exhaust emission reductions due to the higher oxygen content.

The staff also reviewed four emissions test programs that tested ethanol blends and that also included information on the individual hydrocarbon species that could be used to evaluate ozone forming potential. These were (1) the Auto/Oil Test Program, (2) the ARB/ATL Oxygenates Study, (3) the ARB/ATL Phase 1/Phase 2 Gasoline Test program, and (4) the API Test Program. The data from these programs show that there is little variation in the reactivity of the exhaust emissions from different fuels. The data do show that evaporative emissions are significantly less reactive (in the range of 30 to 40 percent less reactive) than exhaust emissions. The specific reactivities (a measure of reactivity per unit of emissions) of exhaust and evaporative emissions are similar regardless of the presence or absence of oxygen and the type of oxygenate used. This suggests that the choice of oxygenate has a minor impact on the reactivity of the emissions. However, the increase in evaporative mass emissions from a 1 psi increase in RVP is so substantial that even considering the lower reactivity of evaporative emissions, the resultant ozone forming potential significantly increases when exhaust and evaporative emissions are combined.

Additionally, the U.S. EPA has developed a complex model that refiners must use to demonstrate compliance with the federal RFG regulations. The model is based on data from a large number of emission test programs. Because the complex model for total hydrocarbon emissions contains both exhaust and evaporative emission components, it can be used as a third method to assess changes to exhaust and evaporative emissions due to differences in gasoline properties. Staff used the complex model to assess the predicted differences in total hydrocarbon mass emissions from two gasoline blends reflecting the two gasolines evaluated in the ARB's recent test program. Under the complex model, the elevated RVP gasoline containing 10 percent ethanol results in increases in total hydrocarbons of 3 percent for exhaust emissions and

40 percent for evaporative emissions. When exhaust and evaporative emissions are weighted and combined, the ethanol blend results in an increase in total hydrocarbon mass emissions of 14 percent compared to the complying blend.

II. RECOMMENDATION

The staff recommends that the Board find, pursuant to HSC section 43830(g), that elevated RVP gasoline that contains 10 percent ethanol and is exempt from the RVP standard in the CaRFG regulations results in increased emissions and increased ozone forming potential, not considering NOx, compared to gasoline fully complying with the CaRFG standards. As a result of this finding, gasoline containing 10 percent ethanol would not be exempt from the RVP standard in the CaRFG regulations.

III. BACKGROUND

This chapter begins by describing what the RVP of gasoline represents, how gasoline RVP is affected when ethanol is added, and how adding ethanol to gasoline affects oxygen content. It then reviews the history of the California statutes and regulations on gasoline RVP, in particular the conditional RVP exemption in HSC section 43830 for gasoline containing 10 percent ethanol. This is followed by a description of related ARB regulations on the oxygen content of gasoline, and a description of the federal RFG requirements on gasoline RVP and oxygen content.

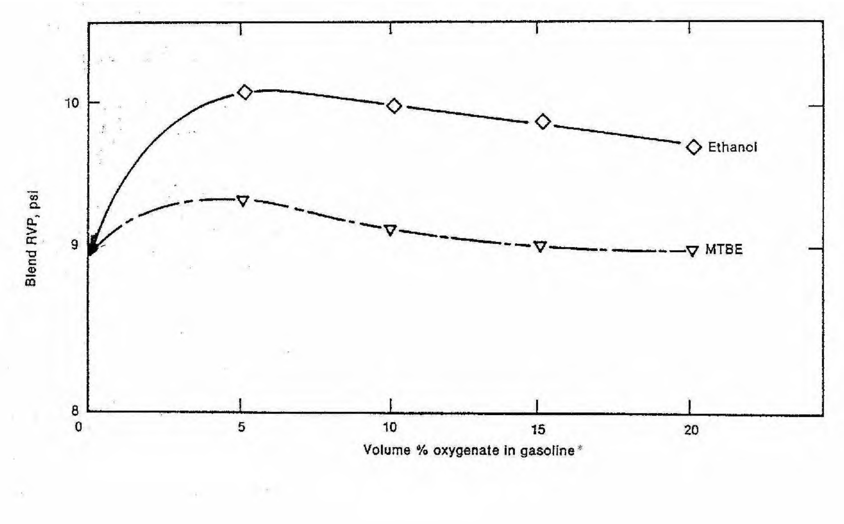
A. The Effect of Ethanol on Gasoline Reid Vapor Pressure and Oxygen Content

Reid vapor pressure is a measure of gasoline volatility. It is expressed in pounds per square inch (psi). Gasoline with a higher RVP is more volatile than gasoline with a lower RVP, and thus has a greater propensity to evaporate. The evaporative emissions from gasoline consist of hydrocarbons, or "reactive organic gases" (there are no carbon monoxide or oxides of nitrogen in evaporative emissions; CO and NOx emissions are products of combustion and are part of the exhaust emissions). Evaporative emissions from gasoline occur during its use, transport and storage. Evaporative reactive organic gas (ROG) emissions from gasoline vehicles occur during four modes of vehicle use, which are referred to as "diurnal emissions," "resting loss emissions," "hot soak emissions," and "running losses."

Adding ethanol to gasoline increases the gasoline's RVP and its propensity to evaporate. The greatest RVP increase occurs with an ethanol content of about five percent ethanol; with increasing ethanol levels the RVP increase is slowly lessened. Figure III-1 shows the RVP effect from blending varying amounts of ethanol and MTBE into gasoline. Adding ten percent ethanol to gasoline with an RVP of 9 psi will raise the RVP by about 1 psi. Adding 10 percent MTBE to the same gasoline results in an RVP increase of about 0.1 psi.

Adding an oxygenate such as ethanol or MTBE introduces oxygen to gasoline. A given volume of different oxygenates will add different amounts of oxygen to the gasoline. Ten percent ethanol results in an oxygen content of 3.5 wt.%, while 10 percent MTBE results in an oxygen content of 1.8 wt.%. Adding up to 3.5 wt.% oxygen to gasoline reduces CO emissions for most cars now on the road and the reduction in CO is proportionate to the oxygen content.

Figure III-1
Effect of Oxygenate Concentration on Vapor Pressure



Note: Base gasoline —Indolene HO III.
(See reference 33)

B. California Statutes and Regulations on the RVP of Gasoline

1. Basic RVP Requirements

In 1970, the California Legislature enacted a statute — renumbered as HSC section 43830 in 1975 — that directed the ARB to require that California gasoline have an RVP of no more than nine pounds per square inch. The standards were to be applicable only during the time periods and in the places the Board determined necessary. In early 1971, the Board adopted an RVP standard of nine psi, applicable in all but one of the state's 14 air basins in specified summer months that varied among the air basins (section 2250, title 13, CCR). Along with a "bromine number" regulation for gasoline in the South Coast Basin adopted the same year, the RVP regulation was the first motor vehicle fuels standard adopted by the ARB.

The RVP standard of nine psi for California gasoline applied for 21 years, from the spring of 1971 until the spring of 1992. At that time it was replaced by a more stringent RVP standard of 7.8 psi that was part of the ARB's Phase 1 reformulated gasoline regulations adopted following a September 1990 hearing (in that year the RVP statute was amended to make clear the ARB had authority to establish a RVP standard lower than nine psi). The ARB adopted its Phase 2 RFG regulations after a November 1991 hearing. These regulations, which became applicable in the spring of 1996, imposed a yet more stringent RVP standard of 7.0 psi that has remained in effect since then. In the South Coast Air Basin, one of the areas with the longest RVP seasons, the RVP standard applies to gasoline supplied from refineries from March 1 to October 31.

2. State Laws on the RVP Standard for Gasoline Containing 10 Percent Ethanol

In 1980, the Legislature enacted an urgency bill amending HSC section 43830 to exempt gasoline containing at least 10 percent ethanol from the ARB's standard for RVP as long as the gasoline used in the blend met the RVP standard of nine psi. The exemption was for three years. The need for urgency action was based on a finding that, in the face of decreasing supplies of gasoline, the immediate widespread use of blends of alcohol and gasoline could reduce gasoline consumption by 10 percent. The original temporary exemption for gasoline containing 10 percent ethanol was extended by legislation enacted in 1983 (until January 1, 1987), in 1986 (until January 1, 1990), and in 1988 (until October 1, 1993).

The current RVP exemption for gasoline containing 10 percent ethanol, and the provisions regarding the finding that are the subject of this report, were enacted in 1991 by Senate Bill 1166, authored by Senator Hill (stats 1991 ch 1194). There have been no further amendments to the RVP statute since then. The full text of HSC section 43830 is set forth in Appendix A. SB 1166 added three new subsections, which applied after the previously enacted exemption ended September 30, 1993. Section 43830(f) applied from October 1, 1993 to December 31, 1995 — the remaining period when the ARB's Phase 1 RFG regulations were expected to apply. Section 43830(g) applied starting January 1, 1996 — when the ARB's Phase 2 RFG regulations, then under consideration, were expected to apply. Section 43830(g) provides as follows:

> (g) On and after January 1, 1996, any blend of gasoline of at least 10 percent ethyl alcohol shall not result in a violation of the Reid vapor pressure standard adopted by the state board pursuant to this section unless it is determined by the state board on the basis of independently verifiable automobile exhaust and evaporative emission tests performed on a representative fleet of automobiles that the blend would result in a net increase in the ozone forming potential of the total emissions, excluding emissions of oxides of nitrogen, when compared to the total emissions, excluding emissions of oxides of nitrogen, from the same automobile fleet using gasoline that meets all applicable specifications for Phase II gasoline established by the state board.

C. Related ARB Regulations on the Oxygen Content of Gasoline

1. The 1992 - 1996 Interim Wintertime Oxygenates Regulation

Before 1992, the ARB did not have any regulations either prohibiting or requiring specified levels of oxygen in gasoline. From 1980 to 1992, ethanol was used in roughly five percent of the gasoline in California. Largely because of tax considerations and the RVP exemption, the ethanol content was usually ten percent by volume, resulting in an oxygen content of about 3.5 wt.%. During the RVP season, the gasoline containing 10 percent ethanol was exempt from the ARB's RVP standard.

The 1990 amendments to the federal Clean Air Act added section 211(m), which conditionally requires states having areas with federally-designated unhealthy levels of CO to establish a program requiring that the wintertime gasoline in those areas contain at least 2.7 wt.% oxygen (CO concentrations are typically highest in the winter). The required state oxygenated gasoline regulations, to start November 1992, had to be submitted to U.S. EPA as a revision of the State Implementation Plan (SIP) for the area. The law directed U.S. EPA to waive the requirement, allowing a state to require less of the oxygen additives, if the state shows that fuels with 2.7 wt.% oxygen would worsen unhealthy levels of other air pollutants.

California had eight CO nonattainment areas that triggered the wintertime oxygenates requirements in the federal CAA. Following hearings in November and December 1991, the ARB adopted two regulatory programs requiring oxygen in gasoline.

The first program was the interim oxygen regulation for wintertime gasoline applicable from November 1992 through February 1996. This program established a minimum oxygen content standard for all California wintertime gasoline to reduce CO emissions from motor vehicles. However, the Board concluded from available test data that increasing the oxygen content of gasoline beyond about 2 wt.% will *increase* overall motor vehicle emissions of NOx. NOx emissions contribute to the formation of ground-level ozone — the primary constituent of "smog" — and to atmospheric particulate matter (PM). During the winter, most urban areas of California exceed the federal and state ambient air quality standards for PM (which like CO is most highly concentrated in the winter) and some areas exceed the ambient standards for ozone (which is worse in the summer).

To avoid significant increases in vehicle NOx emissions as a result of the winter oxygen requirements, the Board adopted a minimum wintertime oxygen limit of 1.8 wt.% *and* a maximum limit of 2.2 wt.% (§2258, title 13, CCR). The ARB reasoned that this approach would be sufficient to attain compliance with the ambient standard for CO in the coming years while minimizing the extent to which the increased use of oxygen in winter gasoline would interfere with attainment of the ambient standards for PM and ozone. During the November 1992 - February 1996 period, the ARB did not impose a summertime maximum oxygen limit.

2. The CaRFG Program

Beginning March 1996, the interim regulation on wintertime oxygenates was replaced by the second ARB gasoline program adopted in 1991 — the comprehensive Phase 2 reformulated gasoline (CaRFG) regulations (§§ 2260 - 2272, title 13, CCR) also known as the cleaner burning gasoline program. The CaRFG regulations establish standards for eight different gasoline properties. The standards are designed to achieve maximum reductions in emissions including organics, NOx, oxides of sulfur (SOx), potency weighted toxics, and wintertime CO.

In light of the federal RFG requirements for oxygen described below, the Board included a provision that when gasoline is shipped from the refinery, it must contain at least 1.8 wt.% oxygen year-round. Because of its concern with potential NOx increases resulting from the mandated use of oxygen, the Board also imposed a year-round upper oxygen limit of 2.2 wt.% for gasoline being shipped from the refinery. In anticipation of the development of the predictive model mechanism described below, the original regulations imposed a minimum oxygen requirement of 1.8 wt.% throughout the gasoline distribution system only during the winter periods that had been in the interim oxygenates regulation—during the rest of the year, the Predictive Model would be available for refiners wishing to reduce or eliminate the use of oxygen. The initial CaRFG regulations similarly imposed a year-round maximum oxygen limit of 2.7 wt.% throughout the gasoline distribution system.

Compared to the Phase 1 RFG regulations, the CaRFG program resulted in emissions reductions from on-road gasoline-powered vehicles of about 17 percent for hydrocarbons, about 11 percent for NOx, and about 40 percent for potency-weighted toxics.

As implemented, the CaRFG regulations have allowed refiners to use the "California Predictive Model" to vary the properties of a gasoline formulation as long as the model shows that emissions of hydrocarbons, NOx, and potency-weighted toxics will not increase compared to a blend meeting all of the cleaner-burning gasoline specifications. The Board adopted the California Predictive Model in 1994. The model is based on a wide variety of test programs evaluating the effect of fuel properties on emissions, and indicates that increases in oxygen content will increase emissions of NOx and potency weighted toxics, and will decrease exhaust emissions of hydrocarbons and CO. A refiner is allowed to ship gasoline from the refinery with an oxygen content between 2.2 and 2.7 wt.% if the refiner demonstrates through use of the Predictive Model that changes to other properties of the gasoline formulation will offset the NOx and toxics emission increases associated with the oxygen. The refiner can also use the Predictive Model to ship gasoline from the refinery with less or no oxygen outside the specified winter period.

The California air pollution programs have been successful at reducing ambient concentrations of CO in the areas that have experienced exceedances of the federal ambient CO standard. The U.S. EPA recently approved redesignation to attainment for all nonattainment areas in California except Los Angeles - South Coast Air Basin (63 FR 15303 (March 31, 1998)).

3. The August 27, 1998 Hearing on Amendments to the Oxygen Content Provisions in the CaRFG Regulations

Earlier this year, ARB staff proposed regulatory amendments making two significant changes to the provisions on oxygen content in the CaRFG regulations. The amendments were designed to give refiners more options on oxygen content so they would have more flexibility in meeting the CaRFG requirements.

The first proposed change resulted from the recent CO attainment redesignations. The staff proposed elimination in a major portion of the state of the requirement for at least 1.8 wt.% oxygen in gasoline sold in the winter. Under the proposal, the requirement would only remain in the counties of Los Angeles, Orange, Riverside, San Bernardino, Ventura and Imperial, as well as in Fresno and Madera Counties and the Lake Tahoe Air Basin through January 31, 2000, only. In the areas where the wintertime requirement was removed and which are not subject to a year-round federal oxygenate requirement, refiners would be able to use the Predictive Model to reduce or eliminate the oxygen in their gasoline year-round. Refiners are required by the federal RFG regulations to have at least 2.0 wt.% oxygen in Sacramento and most of Southern California, so that these areas would still not have the flexibility needed to market oxygen-free gasoline.

The second proposed change was to increase in the maximum oxygen content “cap” limit from 2.7 to 3.5 wt.% year-round for gasoline for which the Predictive Model is used. An oxygen content of 3.5 wt.% is equivalent to an ethanol content of about 10 percent. Because the Predictive Model shows a NOx increase associated with increases in oxygen content, a refiner wishing to increase oxygen content to 3.5 wt.% would have to offset the NOx increase by changing the specifications for other properties. Since the model also shows an exhaust hydrocarbon decrease associated with the oxygen increase, the refiner would have more leeway with other properties that affect hydrocarbon emissions.

At the August 27, 1998 hearing on the staff proposals, the Board adopted the amendments to the wintertime minimum oxygen requirements and those amendments went into effect on September 21. However, the Board was concerned that allowing up to 10 percent ethanol in CaRFG through use of the Predictive Model could allow 10 percent ethanol blends that would qualify for the HSC section 43830(g) exemption from the RVP standard, which could result in an increase in mass emissions and ozone forming potential. ARB staff indicated it was planning to present a recommendation on the section 43830(g) determination at the Board’s December 10, 1998 meeting. The Board accordingly decided to continue consideration of the oxygen cap amendment to the December 10 meeting, so that it could considered both the determination and the regulatory change to allow up to 3.5 wt% oxygen at the same time.

D. Related Federal Reformulated Gasoline Requirements

The 1990 amendments to the federal CAA also added section 211(k), which directed U.S. EPA to adopt federal RFG regulations applicable starting January 1995 in the nine major metropolitan areas of the country with the worst ozone pollution. These areas included the greater Los Angeles area and San Diego County. Because its ozone nonattainment status was “bumped up” to severe, the greater Sacramento area became subject to the federal RFG requirements in June 1996. Thus about 70 percent of all the gasoline sold in California must meet the federal RFG standards. About 30 percent of the gasoline sold nationwide is subject to the federal RFG requirements, because it is sold in either a mandatory federal RFG area or an area that has opted-in to the program.

The federal CAA requires that federal RFG contain no more than one percent benzene, no heavy metals, and at least 2.0 wt.% oxygen year-round (the U.S. EPA has given refiners the option of averaging at 2.1 wt.% with no batch of gasoline having less than 1.5 wt.% oxygen). The Act further requires a “Phase 1” 15 percent reduction in both summertime volatile organic compounds (VOCs) and toxic emissions in 1995, and an additional 10 percent reduction in 2000 for Phase 2.

The U.S. EPA implemented the Phase 1 element by requiring refiners to certify their gasoline using the federal "complex model" or, during 1995 - 1997, the federal "simple model." In southern tier states including California, the simple model included a maximum RVP limit of 7.2 psi in the summer. The complex model includes RVP as one of the variables. Because of the evaporative emission increases associated with RVP increases, it is not practical for gasoline to meet the complex model summertime requirements for California if the RVP exceeds 7.2 - 7.4 psi.

Neither the federal complex model nor the simple model affords any special RVP treatment for gasoline containing ethanol.[2] Thus even if the Board does not make the HSC section 43830(g) determination on comparative ozone forming potential of gasoline subject to the RVP exemption, the 70 percent of California summertime gasoline that is subject to the federal RFG standards would still have to meet stringent federal RVP requirements without any waiver or exemption for ethanol blends.

[2] Separate from the federal RFG program, federal CAA section 211(h) directed U.S. EPA to adopt nationwide summertime RVP standards with a 1 psi waiver for gasoline containing 10 percent ethanol. In adopting the federal RFG regulations, U.S. EPA considered the option of allowing a similar 1 psi allowance for gasoline containing ethanol. The Administrator rejected this option, concluding that, "The 1 psi waiver for example, could easily forfeit all VOC emission reductions otherwise achieved by the reformulated gasoline program." (59 F.R. 7720 (February 16, 1994).)

IV. SUMMARY OF THE ARB MOTOR VEHICLE EMISSION TEST PROGRAM ON ELEVATED RVP GASOLINE CONTAINING 10 PERCENT ETHANOL

This chapter summarizes the methodology and results regarding comparative ozone forming potential of the recently completed ARB motor vehicle emission test program on elevated RVP gasoline containing 10 percent ethanol. Appendix B contains a more detailed report on this test program.

The 12 vehicle test program took more than two years to complete and cost over $1 million in equipment and resources. The enhanced evaporative emissions tests conducted are resource and time intensive. Although we performed a two-day diurnal test (instead of a three day), it takes one week to complete evaporative emissions tests on one vehicle on one fuel (or one month to complete the exhaust and evaporative emissions test on one vehicle assuming a seven day work week). Additionally, the need to speciate the test samples to allow the evaluation of the ozone forming potential required substantial development work since it is not part of the established exhaust or evaporative test procedures. Speciating the test samples is expensive and contributed significantly to the overall cost of the project.

A. Ethanol Test Program Methodology

1. How Was the Test Program Developed?

The ARB established a workgroup consisting of representatives from the ethanol industry, the automotive industry, the oil refining industry, the U.S. EPA, ARB staff, and other interested parties (the Ethanol Workgroup) to assist in defining the scope of the test program. The workgroup's knowledge of fuels and motor vehicle emissions was critical in the development of the test program.

2. What Two Gasoline Blends Were Compared?

The vehicle emission tests were conducted using two gasoline blends created from the same base gasoline blend stock, which is typical of the non-oxygenated fuel used as the base for CaRFG. The target properties were chosen so that the fully complying gasoline would be a typical summer California gasoline just meeting all of the required flat limit specifications[3] for CaRFG and which used the most common oxygenate in California—MTBE. The gasoline containing 10 percent ethanol was blended to meet all of the required flat limit specifications for CaRFG except for oxygen content and RVP. The gasoline containing ethanol had an oxygen content of about 3.5 wt.% and an RVP of about 8 psi. The fully complying gasoline had an oxygen content of about 2 wt.% and an RVP of about 7 psi.

[3] The CaRFG specifications include aromatic, olefin, benzene, sulfur and oxygen content limits. Also specified are the distillation temperatures for the 50% point (T50) and the 90% point (T90) as well as the RVP.

3. What Vehicles Were Tested?

Emissions tests were performed on 12 vehicles which were obtained from owners in the greater Los Angeles area after being selected randomly using the California Department of Motor Vehicles ownership database. The 12 vehicles are listed in Table 2 (page 6) of Appendix B, along with their respective engine families, evaporative control systems, and emission control technologies.

The vehicles covered a range of model years from 1990 through 1995. This range was chosen because it represents the emission control technology found in a large segment of the California vehicle fleet. All vehicles tested have three-way catalysts (TWCs) and fuel injection. These technologies were introduced in the early 1980's and are used on virtually all 1986 and newer model year light-duty vehicles. The test vehicles are representative of normal and moderate emitting vehicles with TWCs and fuel injection and similar vehicles that are high emitting due to non-optimal emission control systems but are not considered in disrepair. The categories of vehicles represented by the test vehicles account for about 70 percent of the vehicle miles traveled for 1998 and account for about 30 percent of reactive organic gas emissions, about 40 percent of CO emissions and about 50 percent of NOx emissions from on-road gasoline-fueled motor vehicles in California. None of the test vehicles were certified to the ARB's enhanced evaporative emission requirements that started being phased-in with the 1995 model year.

4. What Types of Emission Tests Were Performed?

For exhaust emissions, the 12 vehicles were tested using the Federal Test Procedure (FTP) and a high-speed, high-acceleration (REP05) test procedure. Duplicate tests were performed on each test gasoline blend.

Six of the vehicles underwent diurnal and hot-soak evaporative emissions[4] tests under supplemental 2-day diurnal and hot-soak tests based on the ARB's evaporative emissions test procedures. The test program did not include tests for running loss evaporative emissions because the facilities required were not available. General Motors provided the ARB staff estimates of running loss emissions based on their proprietary vapor generation model. Running loss emissions were also estimated using an ARB draft evaporative emissions model which is based on the U.S. EPA's evaporative emissions model used in the federal RFG program. Staff

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[4] Evaporative emissions of hydrocarbons occur from gasoline vehicles during three modes of use. First, *diurnal emissions* occur while the vehicle is not operating and result from the daily variation in ambient temperature. As the ambient temperature increases throughout the day, some gasoline in the fuel tank vaporizes, and some of the vapors escape to the atmosphere through leaks in the fuel system and emissions control system. Second, *hot soak* emissions have historically originated primarily from the vehicle's carburetor; they occur immediately after the vehicle engine is turned off when gasoline in the carburetor bowl vaporizes due to the temperature increase of the carburetor. The introduction of fuel-injected vehicles in place of carbureted vehicles has resulted in reduced hot soak emissions from newer cars, and all of the vehicles in the ARB test program are fuel-injected. Third, *running losses* occur due to gasoline vaporization while the vehicle is operating. The ARB's enhanced evaporative emission requirements cover all three types of evaporative emissions.

used the ARB's model estimates in conjunction with the speciated hot soak data from the test program to estimate the ozone forming potential of the running loss evaporative emissions. Running loss emissions are difficult to measure but have been shown to be similar to hot soak emissions.

Exhaust and evaporative emissions of total hydrocarbons and non-methane organic gases (NMOG) were measured. Individual organic compounds were quantified (speciated) to allow for the determination of ozone forming potential. Exhaust emissions of CO and NOx were also measured, as were exhaust and evaporative emissions of the four toxic compounds subject to the California Predictive Model — benzene, 1,3-butadiene, formaldehyde, and acetaldehyde.

5. How Were the Exhaust and Evaporative Emissions Combined?

While exhaust emissions are expressed in "grams per mile," evaporative emissions are expressed in "grams per test" for the different evaporative emissions tests. Thus a methodology is always needed to determine how much weight should be given to the different types of emissions in calculating the combined emissions and ozone forming potential from each of the two test fuels. In combining the exhaust and evaporative emissions, the staff used an approach similar to that used in the U.S. EPA's complex model, which also combines the impact of exhaust and evaporative emissions.

The U.S. EPA approach defines "inventory processes" for both exhaust and evaporative emissions, and then combines the emissions using weight factors for the respective processes according to their share of the appropriate emissions inventory. The staff used the California Motor Vehicle Emissions Inventory Version 7G (MVEI 7G) to establish weights for each inventory process (start exhaust, running exhaust,[5] diurnal combined, hot soak, and running loss). The inventory weighting varied for each pollutant of interest. For example, total hydrocarbon emissions are made up (weighted) by exhaust emissions (69 percent) and evaporative emissions (31 percent). Of the exhaust emissions, 55 percent are start exhaust and 45 percent are running exhaust. Evaporative emissions are proportioned by diurnal (28 percent), hot soak (13 percent) and running loss (59 percent).

6. How Was Relative Ozone Forming Potential Determined?

The comparative ozone forming potential for the two fuels was determined using the Carter maximum incremental reactivity (MIR) scale. This scale applies an individual reactivity value to each species of nonmethane organic gas measured in the exhaust and evaporative emissions from the vehicles. The individual MIR values come from the test procedures used to account for relative reactivity in the ARB's low-emission vehicle program. The MIR values have been determined from atmospheric conditions when controlling hydrocarbons have the greatest impact on ozone formation.

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[5] Running exhaust was derived from the results of both the FTP and REPO5 exhaust emission tests, based on information from U.S. EPA on determining the respective contributions of FTP and REPO5 emissions to running exhaust.

The ozone forming potential of the emissions of non-methane organic gas (NMOG)[6] plus CO was also determined. Carbon monoxide was included because advocates of ethanol blends have pointed out that the additional CO emissions benefit expected from the higher oxygen in the ethanol blend would result in a lowering of its overall ozone forming potential. While CO is generally not included in a reactivity-adjusted emissions analysis (for instance, the ozone forming potential of CO is not considered in the ARB's low-emission vehicle regulations), any reduction in CO emissions would reduce the overall ozone forming potential somewhat.

When including CO in the determination of ozone forming potential, staff relied on the test data and the motor vehicle emissions inventory for California. The test data were used to calculate the additional ozone forming potential due to the CO emissions in the tests. This was added to the ozone forming potential of the measured NMOG to determine the total ozone forming potential. In combining the percent change in total ozone forming potential across processes, staff relied on the emissions inventory to determine the appropriate emission proportions (weights) for each process.

7. How Were the Emissions Associated With the Two Fuels Compared?

ARB staff evaluated the test results to determine the overall percent change in the combined exhaust and evaporative emissions. Two different arithmetic averages — percent of the means and mean of percents — were used, and a more formal statistical method which provides a comprehensive examination of the data. The arithmetic averages represent a simple assessment of the data to estimate general trends. The formal method represents a rigorous statistical evaluation of the data that provides refined estimates and allows for evaluation of statistical significance.

B. Emission Test Program on Elevated RVP Gasoline Containing 10 Percent Ethanol — Results and Analyses

Table IV-1 on the next page presents the results of the staff's evaluation of the test data and estimated running loss emissions using the methodologies described above. The three columns on the left reflect an artificial scenario in which there is no difference in running loss evaporative emissions with the two fuels, since running loss emissions could not be directly measured in the test program. The three columns on the right include estimated running loss emissions for the two fuels, derived from an ARB draft evaporative model and the speciated hot soak data from the test program. Additional details of the test data and the staff's evaluation are presented in Appendix B. The complete detailed analyses are presented in reference 1. As shown, all three methodologies give similar results in assessing the percent change in emissions between the elevated RVP gasoline containing 10 percent ethanol and the complying blend. Table 10 of the test report in Appendix B provides the measured emissions for each vehicle tested, as well as the percent change in emissions by vehicle.

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[6] NMOG, which is the organic gas measurement used in the reactivity adjustment mechanism in the low-emissions vehicle regulations, includes oxygenated hydrocarbons that are typically not counted for a hydrocarbon standard.

Table IV-1

Percent Change in Emissions of Elevated RVP Ethanol Blend Compared to Complying Blend*

(Positive Number Indicates an Emissions Increase for the Elevated RVP Ethanol Blend)

Pollutant	**Analysis Method**			**Analysis Method**		
	Percent of Means	Mean of Percents	Formal Method	Percent of Means	Mean of Percents	Formal Method
	Running Loss diff=Zero			**Running Loss Diff.=NonZero**		
Exhaust Only						
CO	-7%	-7%	-10%	-7%	-7%	-10%
NOx	17%	16%	14%	17%	16%	14%
Total Hydrocarbons	8%	5%	3%	8%	5%	3%
Nonmethane Organic Gases	8%	7%	3%	8%	7%	3%
Evaporative Only						
Total Hydrocarbons	27%	26%	25%	55%	54%	52%
Nonmethane Organic Gases	32%	14%	32%	82%	84%	83%
Exhaust and Evaporative Combined**						
Total Hydrocarbons (69/31)	14%	13%	10%	23%	21%	18%
Nonmethane Organic Gases (64/36)	17%	9%	14%	35%	35%	32%
Ozone Forming Potential without CO (73/27)	11%	11%	9%	20%	23%	21%
Ozone Forming Potential with CO (76/24)	8%	8%	6%	16%	19%	17%
Toxics (83/17)	13%	11%	9%	18%	15%	13%
Potency Weighted Toxics (84/16)	5%	4%	1%	9%	6%	5%

* Exhaust emissions consist of FTP and REP05 weighted according to the fraction of daily driving associated with each cycle, based on a U.S. EPA study. Evaporative emissions consist of hot soak, diurnal and running loss weighted according to MVEI7G fractions. Running loss emissions estimated based on ARB's MVEI and an ARB draft evaporative model.

** Weighted proportion of exhaust emissions to evaporative emissions shown in parentheses.

As mentioned above, the test program was developed with the assistance of the Ethanol Workgroup. Staff worked closely with the workgroup through the conduct of the tests and the analysis of the data. The workgroup met on July 15, 1998 and October 22, 1998, at which time the staff's analyses of the data were discussed.

1. Changes in Mass Emissions

Using the formal statistical methodology, exhaust emissions of total hydrocarbons and NMOG from the elevated RVP gasoline containing 10 percent ethanol blend increased by 3 percent. Evaporative emissions of total hydrocarbons and NMOG from the ethanol blend represented major increases of 52 percent and 83 percent, respectively.

For combined exhaust and evaporative emissions, total hydrocarbons increased by 18 percent and NMOG emissions were 32 percent higher for the elevated RVP gasoline containing ethanol blend compared to the complying blend.

In general, the elevated RVP ethanol blend produces lower CO emissions and higher NOx emissions than the complying blend. Under the formal method, exhaust emissions of CO decrease by about 10 percent for the elevated RVP ethanol blend while NOx emissions increase by 14 percent. The CO and NOx responses are primarily due to the different oxygen contents of the two gasolines.

Toxic compounds from the elevated RVP ethanol and complying blends were also evaluated on both a mass and cancer potency adjusted basis. Under the formal method, the combined mass emissions of toxics are 13 percent greater for the elevated RVP ethanol blend than for the complying blend. The combined potency weighted toxics are five percent greater for the elevated RVP ethanol blend than for the complying blend. The four compounds considered in the toxics evaluation are 1,3 butadiene, benzene, formaldehyde and acetaldehyde. EPA requires these compounds to be evaluated as part of their reformulated gasoline program.

We also evaluated the impact of the measured mass of MTBE on total mass toxics and the potency weighted toxics. While MTBE has not been identified as a toxic air contaminant, there is a proposed cancer potency factor[7]. Including MTBE as a toxic results in the elevated RVP ethanol blend having lower total mass toxics compared to the complying blend. However, because the cancer potency of MTBE is significantly less (about an order of magnitude less than acetaldehyde and about three orders of magnitude less than 1, 3 butadiene) than any of the other toxic compounds, adding the MTBE *does not* have a detectable effect on the results for potency weighted toxics. Thus, including MTBE as a toxic still results in the elevated RVP ethanol blend having greater potency weighted toxics than the complying blend.

The formal method also provides an estimate of the relative certainty of the estimated changes. The results show that for NOx, total hydrocarbons, toxics, and potency weighted toxics, the likelihood is 90 to 100 percent that emissions with the elevated RVP ethanol blend are higher than emissions with the fully complying blend, for the test fleet. For CO, the likelihood is almost 100 percent that emissions are higher from the fully complying gasoline than from the ethanol blend which contains a greater percentage of oxygen.

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[7] We used the cancer potency factor proposed by the Office of Environmental Health Hazard Assessment. The proposed factor is 4.5 µg/m^3.

2. Does the Ozone Forming Potential from the Elevated RVP Gasoline Containing 10 Percent Ethanol Blend Increase In Comparison to the Complying Blend?

As shown in Table IV-1, the ozone forming potential (not including the reactivity of CO) of the combined exhaust and evaporative emissions using the formal method is *21 percent higher* for the elevated RVP ethanol blend than for the complying blend. The difference in ozone forming potential is largely due to the substantially higher evaporative mass emissions that result from the higher RVP of the ethanol blend, which overwhelms other factors. This is the case even though the evaporative emissions are about two-thirds as reactive as the exhaust emissions.

Table IV-1 also shows that, when the reactivity of CO is included, the ozone forming potential of the combined exhaust and evaporative emissions using the formal method is still *17 percent higher* for the elevated RVP gasoline containing 10 percent ethanol. The 4 percent reduction compared to ozone forming potential when CO is not considered is due to the fact that the higher oxygen content of the gasoline containing ethanol reduces CO emissions in the exhaust by 10 percent relative to the complying gasoline blend.

Under the formal method of statistical analysis, the likelihood is greater than 95 percent that the elevated RVP ethanol blend results in greater ozone forming potential than the fully complying blend from the test fleet.

Although not required as part of the analyses specified in the HSC section 43830(g), the test program demonstrated that there was a significant increase in NOx emissions on the order of 14 percent from the test fleet when it used the high RVP ethanol blend. By undergoing complex chemical reactions, NOx emissions contribute to increased concentrations ozone, PM_{10}, and NO_2. These in turn can result in exceedances of the ambient air quality standards for these pollutants. Other air quality problems such as reduced visibility and acid deposition can be attributed to emissions of NOx. The Board has recognized the importance of reducing NOx emissions and has implemented several control programs to reduce NOx emissions from motor vehicles.

V. OTHER CONFIRMATORY VEHICLE EMISSION TEST DATA AND ANALYSES

This Chapter outlines staff's use of U.S. EPA's complex models to evaluate the combined mass exhaust and evaporative emissions of total hydrocarbon and CO from an elevated RVP gasoline containing 10 percent ethanol compared to a gasoline meeting all of the CaRFG standards. It then reviews other vehicle emission test programs that have evaluated the effect of oxygen and RVP on exhaust and evaporative mass emissions and reactivity.

A. Comparison of Combined Exhaust and Evaporative Mass Hydrocarbon Emissions Using the U.S. EPA Complex Model

Both the CaRFG regulations and the federal RFG regulations use models to predict the emissions that will result from specified gasoline properties. The models are based on the emission tests in a large variety of test programs. For instance, the ARB's California Predictive Model is based on 7,662 data points generated in 18 different emission test programs designed to analyze the relationship between fuel properties and vehicular emissions.

The CaRFG regulations establish a single summertime RVP standard of 7.0 psi that applies throughout the distribution system. Because of the important role RVP plays in emissions and the enforcement benefits from a single standard, RVP is the only regulated property that refiners are not allowed to vary using the California Predictive Model. RVP is also, of the eight regulated CaRFG properties, the one that has the most significant impact on evaporative emissions. Accordingly, the California Predictive Model holds RVP at a constant maximum of 7.0 psi and only addresses the properties affecting exhaust emissions. Thus, while the California Predictive Model can be very useful in predicting the exhaust emissions impacts of the higher oxygen content of the elevated RVP gasoline containing 10 percent ethanol, it will not predict either that gasoline's mass evaporative emissions impact or its combined mass evaporative and exhaust emissions impact. However, the design of U.S. EPA's complex model is such that it *can* be useful in evaluating these issues.

1. Overview of U.S. EPA's Complex Model

As part of the development of the federal RFG regulations, U.S. EPA developed several mathematical models, which it refers to as complex models.[8] The complex models are equations which relate vehicular emissions to the properties of the gasoline burned by the vehicle. These models allow one to estimate the change in motor vehicle emissions when the properties of gasoline change. The models are based on all of the vehicle emission test data that were available to U.S. EPA and met the agency's criteria. Under the federal RFG program, gasolines must meet specific emission reduction criteria as established by the Federal Clean Air Act.
U.S. EPA's complex models are used to determine if these emissions criteria are met.

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[8] U.S. EPA referred to these as "complex models" to distinguish them from a "simple model" that refiners were allowed to use from 1995 through 1997 only.

The U.S. EPA complex model has separate models for NOx emissions, total hydrocarbon emissions, and total toxics emissions. The model for total hydrocarbon emissions is composed of an exhaust hydrocarbon model and an evaporative hydrocarbon model. The fuel properties included in U.S. EPA's models are gasoline RVP, aromatic hydrocarbon content, olefinic hydrocarbon content, sulfur content, benzene content, oxygen content, oxygenate type, percent distilled at 200 degrees F, and percent distilled at 300 degrees F. U.S. EPA's NOx emission model and exhaust hydrocarbon emission model each are composed of two "submodels" — one for "normal" emitting vehicles and one for "high" emitting vehicles. The development of separate models for normal emitting vehicles and for high emitting vehicles was U.S. EPA's attempt at recognizing that emissions from these two groups of vehicles might respond differently to changes in fuel properties.[9]

Because U.S. EPA's complex model for total hydrocarbon emissions contains both an exhaust model component and an evaporative model component, it can be used to help assess the emissions changes resulting from fuel property changes that affect both evaporative and exhaust emissions changes. Thus the evaporative emissions increase resulting from an elevated RVP gasoline that contains 10 percent ethanol and is exempt from an RVP standard of 7.0 psi can be estimated with the use of the EPA's complex models. The evaporative emissions impact from the 10 percent ethanol blend can then be added to the exhaust emissions estimates predicted by the model. This combined mass emissions prediction can then be compared with a similar prediction under the complex model for a gasoline that fully complies with the CaRFG standards to determine the difference in total emissions between the two gasolines.

2. Predicted Emissions Using U.S. EPA's Complex Models

The staff used the U.S. EPA's complex model for total hydrocarbon emissions to make emissions predictions for two fuels — one just meeting the flat limit requirements in the CaRFG regulations, and the other having an RVP of 8.0 psi, an oxygen content of 3.5 wt.% (ethanol), and just meeting all the remaining flat limit requirements. Table V-1 shows the fuel properties used to generate the model predictions; they are essentially the same as the fuels evaluated in the ARB test program. Table V-2 shows the predicted exhaust, evaporative and combined total hydrocarbon mass emissions for each gasoline blend and the percent difference. The Table V-2 also shows the comparative emissions of NOx and total toxics. As the tables show, this analysis indicates that the U.S. EPA Complex model predicts that elevated RVP ethanol blends generally will have higher total hydrocarbon emissions than an oxygenated gasoline that meets the RVP standard.

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[9] The ARB did not pursue the two models because it was believed that not enough data existed for a separate model for high emitting vehicles and that true high emitting vehicles were malfunctioning and should be addressed as such. As mentioned previously, we also believe that it is very difficult to determine the true fuel effects, which are relatively small, from the much larger test-to-test variability exhibited by high emitting vehicles. The ARB approach is consistent with data and recommendations from the Auto/Oil Program.

Table V-1
Properties of Fuels Used to Generate Model Predictions

Property	Complying Blend	Ethanol Blend
Reid vapor pressure (RVP), psi, max	7.0	8.0
Benzene, vol %, max	1.00	1.00
Sulfur, ppmw, max	40	40
Aromatic HC, vol %, max	25	25
Olefins, vol %, max	6.0	6.0
Oxygen, wt %	2	3.5
T50 (temperature at 50 percent distilled) deg. F	210	210
T90 (temperature at 90 percent distilled) deg. F	300	300

Table V-2
Predictions Using U.S. EPA's Complex Model

Pollutant	Complying Fuel (mg/mi)	Ethanol Blend (mg/mi)	Percent Difference
Evaporative Total Hydrocarbons	311	435	40
Exhaust Total Hydrocarbons	749	773	3
Combined Total Hydrocarbons	1,060	1,208	14
NOx	1,162	1,164	0
Total Toxics	61	63	2

Based on U.S. EPA's complex model, an elevated RVP gasoline that contains 10 percent ethanol and is exempt from the RVP standard of 7.0 psi would increase exhaust total hydrocarbons mass emissions by 3 percent and would increase the evaporative total hydrocarbon mass emissions by 40 percent, for a 14 percent increase in combined evaporative and exhaust total hydrocarbon mass emissions. Emissions of total toxics would increase by about 2 percent. This is directionally consistent with the results from the ARB ethanol test program discussed earlier.

B. Summary of Data on the Effect of RVP and Oxygen on Emissions

1. RVP Effects on Mass Emissions

The Auto/Oil Air Quality Improvement Program, the U.S. EPA Complex Model, and the ARB predictive model indicate that RVP has a small effect on exhaust hydrocarbon emissions. RVP also has an effect on carbon monoxide and NOx emissions. These evaluations of the data indicate that increasing RVP from 7 to 8 psi could increase exhaust hydrocarbon by 0.4 percent, CO by 3.4 percent, and NOx by 4.5 percent.

Evaporative hydrocarbon emissions are principally a function of RVP; increasing the RVP increases the evaporative emissions. Thus ethanol, with its substantial effect on RVP, will increase evaporative hydrocarbon emissions whenever the RVP of the base gasoline remains constant. As shown previously, the evaporative component of the U.S. EPA complex model predicts that increasing RVP from 7 to 8 psi will increase the evaporative hydrocarbon emissions from the gasoline by an estimated 40 percent.

Table V-3 summarizes information from emission test programs on the effects of RVP on emissions.

Table V-3
Summary of the Effects of RVP on Mass Exhaust and Evaporative Emissions

FACTOR	SUMMARY OF SCIENCE	SUMMARY OF SUPPORTIVE EVIDENCE
RVP: Exhaust Emissions	Increasing RVP from 7 to 8 psi will increase exhaust hydrocarbon, carbon monoxide, and oxides of nitrogen emissions. The magnitude of change is 0.4, 3.4, 4.5 percent, respectively.	The ARB's predictive model — based on 20 emission test studies that included approximately 7,700 exhaust emission tests using 1,100 vehicles.
RVP: Evaporative HC Emissions	Increasing RVP will substantially increase the evaporative hydrocarbon emissions from the gasoline by an estimated 40 percent.	U.S. EPA Complex Model Emission Results of Oxygenated Gasolines and Changes in RVP (Technical Bulletin # 6), Auto/Oil Air Quality Improvement Program, September 1991

2. Effect of Gasoline Oxygen Content on Mass Emissions

There have been many motor vehicle emission test programs that have evaluated the effect of oxygen on emissions. Adding oxygen to gasoline will lean out the air to fuel mixture. In general, this leaning effect results in decreased exhaust emissions of carbon monoxide and hydrocarbons and an increase in emissions of NOx. These effects are consistent with combustion theory and are supported by empirical data from a large number of motor vehicle test programs. Generally, the exhaust emissions testing indicates that the response to oxygen is independent of the oxygenate used to supply it. However, different oxygenates impact RVP differently. For example, ethanol will increase the RVP of the blend by about 1 psi, while ETBE will decrease it slightly. MTBE and TAME have only a small effect on RVP. Tables V-4 and V-5 summarize these effects.

Table V-4
Summary of the Effects of Oxygen on Exhaust and Evaporative Emissions

FACTOR	SUMMARY OF SCIENCE	SUMMARY OF SUPPORTIVE EVIDENCE
OXYGEN: **Exhaust and Evaporative Emissions**	Adding oxygen to gasoline will lean out the air to fuel mixture. In general, this leaning effect results in decreased emissions of carbon monoxide and hydrocarbons and increase in emissions of oxides of nitrogen. These effects are consistent with combustion theory and are supported by empirical data from a large number of motor vehicle tests programs. Generally, it is accepted that the exhaust emissions response to oxygen is independent of the oxygenate used to supply it. However, different oxygenates impact RVP differently. For example, ethanol will increase the RVP of the blend by about 1 psi, while ETBE will decrease it slightly. MTBE and TAME have only a small effect on RVP. Thus, ethanol with its greater effect on RVP will have increased HC evaporative emissions.	The ARB's predictive model -- based on 20 emission test studies that included approximately 7,700 exhaust emission tests using 1,100 vehicles. Emission Results of Oxygenated Gasolines and Changes in RVP (Technical Bulletin # 6), Auto/Oil Air Quality Improvement Program, September 1991 Auto Oil Final Report, January 1997 Gasoline Reformulation and Vehicle Technology Effects on Exhaust Emissions (Technical Bulletin #17), Auto/Oil Air Quality Improvement Program, August 1995 Effect of Use of Low Oxygenate Gasoline Blends on Emission from California Vehicles, Automotive Testing Lab for ARB, February 1994 Automotive Testing Lab Study for EPA- 1991

TABLE V-5
SUMMARY OF MAJOR DATA ON THE EFFECTS OF OXYGEN ON EMISSIONS

STUDY AND DATE	FLEET TYPE	FUELS COMPARED	RESULTS	CERTAINTY
Emission results of Oxygenated Gasolines and Changes in RVP (Technical Bulletin # 6), Auto Oil Air Quality Improvement Program, September 1991	20 cars -- 1989 model year	7 non-oxygenated fuel and oxygenated fuel -- 4 with 10% EtOH 7 2 with 15% MTBE 1 with 17% ETBE	The use of oxygenates resulted in an average decrease in CO and exhaust THC emissions of about 13 and 6 percent, respectively, while NOx emissions increased by about 5 percent, on average.	High -- well designed test program involving enough fuels and vehicles to identify fuel effects on vehicle emissions.
Gasoline Reformulation and Vehicle Technology Effects on Exhaust Emissions (Technical Bulletin #17), Auto/Oil Air Quality Improvement Program, August 1995	29 cars --1983 to 1994 model years.	A non-oxygenated and a 15% MTBE blend.	On average the oxygenated (MTBE) gasoline resulted in a reduction in: -11% in CO emissions -6 % in THC emissions +4 % in NOx emissions	High -- well designed test program involving enough vehicles to and identify the effects fuel oxygen content on vehicle emissions.
Effect of Use of Low Oxygenate Gasoline Blends Upon Emission from California Vehicles, Automotive Testing Lab for ARB, February 1994	13 cars -- 1973 to 1991 model years.	8 non-oxygenated fuels and 8 oxygenated fuels 4 ethanol blends (5.7 to 7.8 percent ethanol), 2 MTBE (11% and 15%), and 2 ETBE fuels (12.7% and 17.2 percent ETBE)	The use of oxygenates result in: -4% THC emissions -7% CO emissions +3% NOx emissions increased by about 3 percent for 2.7 wt.% oxygen and no increase for 2 wt.% oxygen.	Moderate — fewer cars over wide range of technology makes it difficult to separate fuel and vehicle effects
Effects of Fuel RVP and Fuel Blends on Emissions at Non-FTP Temperatures, American Petroleum Institute, July 1991	11 vehicles --1981 to 1989 model year.	A total of 11 fuels were tested. Two base fuels of 10 psi and 7 psi with no oxygen. Four 13 psi fuels: Base, 10% EtOH, 15% MTBE, 7.5% MTBE. Five 9 psi fuels: Base, 10% EtOH, 15% MTBE, 7.5% MTBE, and 17.1% ETBE	Increasing fuel oxygen from 0 to 2.0 weight % showed: +5.4 % in NOx -3.7 in Exhaust HC Ethanol increase RVP 0.8 to 1.0 psi, ETBE reduced RVP 1.1 psi, and MTBE results in a negligeble change in RVP	Moderate — not as many vehicles as the Auto/Oil study.

3. Effect of Different Oxygenates on the Reactivity of Emissions

Two prior studies — the Auto/ Oil study reported in Technical Bulletin #6 and the ATL "Phase 1/ Phase 2" study conducted for ARB — yielded speciated emissions data that can be used to compare the specific reactivity of the nonmethane organic gas emissions when different oxygenates are used. Specific reactivity is a measure of how much ozone would be produced by a unit of mass emissions, and is typically expressed as grams of ozone per gram of NMOG. The test fuels used in these test programs were made by blending ethanol and MTBE with the same base gasoline. These fuels are very similar in their hydrocarbon composition and thus provide a good basis to evaluate the effect of a particular oxygenate on specific reactivity.

Table V-6 contains specific reactivity data for the two studies and for the ARB's recently completed study on elevated RVP gasoline containing 10 percent ethanol. As can be seen from the table, the evaporative emissions are 22 to 39 percent less reactive than exhaust emissions; this difference in reactivity has been incorporated into staff's analysis of the ethanol blend test program. Table V-6 also shows that when one compares the difference in specific reactivity of the combined exhaust and evaporative emissions from gasoline oxygenated with ethanol and gasoline oxygenated with MTBE, the difference in reactivity is very small. Since these data are from three different test efforts and generally show the same relationship, it is unlikely that additional vehicle emission tests would provide data that would change the current assessment of reactivity benefits associated with ethanol blends.

Table V-6
Specific Reactivities of Gasolines

(1) Auto/Oil Air Quality Improvement Research Program, see Ref. 20.
(2) Air Resources Board, see Ref 3.

	AVERAGE SPECIFIC REACTIVITY				RELATIVE REACTIVITY	
	EXHAUST		EVAPORATIVE		EVAPORATIVE / EXHAUST	
STUDY	MTBE	EtOH	MTBE	EtOH	MTBE	EtOH
A/O (1)	3.07	3.26	1.81	1.90	0.59	0.58
ARB ATL PHASE1/PHASE2 (2)	3.37	3.43	2.46	3.02	0.73	0.88
ARB EtOH STUDY (3)	3.53	3.50	1.97	1.43	0.56	0.41
Average	3.33	3.39	2.08	2.12	0.62	0.62

(3) Air Resources Board, see Ref. 1.

4. Evaluating Comparative Ozone Forming Potential Using Data From Prior Studies

Table V-7 summarizes prior test data on the impact of a 1 psi increase in RVP on the ozone forming potential of exhaust and evaporative emissions. These data indicate that an increase in RVP associated with the use of ethanol in gasoline will result in a net increase in vehicle mass emissions. The data also show that the increase in mass emissions from the higher volatility gasoline with ethanol results in an overall increase in the ozone forming potential of the emissions. This is consistent with the results from the ARB ethanol test program discussed in Chapter IV.

TABLE V-7

SUMMARY OF MAJOR DATA THAT INDICATES THE EFFECTS OF RVP ON OZONE FORMING POTENTIAL

STUDY AND DATE	FLEET TYPE	FUELS COMPARED	RESULTS	
Effects of Fuel RVP and Fuel Blends on Emissions at Non-FTP Temperatures, American Petroleum Institute, July 1991	11 vehicles -- 1981 - 1989 model year.	A total of 11 fuels were tested. Two base fuels of 10 psi and 7 psi with no oxygen. Four 13 psi fuels: Base, 10% EtOH, 15% MTBE, 7.5% MTBE. Five 9 psi fuels: Base, 10% EtOH, 15% MTBE, 7.5% MTBE, and 17.1% ETBE.	Only mass emissions measured. The study found that: Change of RVP has no significant effect on CO emission at 35º F and 55 ºF. At 80 ºF, a significant reduction in CO occurs as a result of lowering fuel vapor pressure from 13 psi to 10 psi. Increasing oxygen content showed increased NOx emissions (5.4%)and decreases in exhaust hydrocarbon emissions (3.7%). Lowering fuel RVP produced reduction in both diurnal and hot soak evaporative emissions.	
			MASS	REACTIVITY
Emission Results of Oxygenated Gasolines and Changes in RVP (Technical Bulletin # 6), Auto Oil Air Quality Improvement Program, September 1991	20 cars -- 1989 model year	7 non-oxygenated fuels and 7 oxygenated fuels -- 4 with 10% EtOH, 2 with 15% MTBE, and 1 with 17% ETBE	Effect of adding 10% ethanol (with RVP increase) and 15% MTBE compared to unoxygenated base gasoline: 10% Ethanol / 15% MTBE THC 12.7% 2.0% CO 17.5% 2.5% NOx -0.4% 6.7% Diurnal 116% 1.0% Hot Soak 12.6% -15.0%*	Effect of adding 10% ethanol (with RVP increase) and 15% MTBE compared to unoxygenated base gasoline: 10% Ethanol / 15% MTBE OFP-MIR 8.1% - 0.2% OFP-MOR 8.6% 1.1%
ATL "Phase 1, Phase 2"	6 vehicles -- 1978 to 1990 model years	11% MTBE, RVP 6.6 psi 5.7% EtOH, RVP 7.6 psi.	Exhaust 14% Running loss 200% Diurnal 75% Hot Soak 875%	Ozone/mi** Percent increase in emissions due to increase in RVP from ethanol Exhaust 18% Running loss 3veh: 310% 3veh: 40% Diurnal 80% Hot Soak 3veh: 500% 3veh: 20%

* Other test programs have not seen this effect.
** Ozone forming potential is mass x the MIR (maximum incremental reactivity) factors

5. Fuel Effects in Older Vehicles

The Auto/Oil research program, the API study, and the ARB/ATL Low Oxygenates and Phase 1 Phase 2 test programs all tested vehicles older than those in the recent ARB test program. As discussed in Section VI.B.3, the older vehicles responded directionally to oxygen and RVP in the same ways as those in the ARB test program.

VI. CONSISTENCY OF THE STAFF'S ANALYSIS WITH THE CRITERIA IN HEALTH AND SAFETY CODE SECTION 43830(g)

This chapter discusses whether the staff's analysis of the data from the ARB test program satisfies the criteria in HSC section 43830(g). It is important to note that the staff is additionally relying on the substantial amount of additional data from the other test programs and analyses that confirm the overall finding from the test fleet.

A. The Health and Safety Code Section 43830(g) Requirements

Health and Safety Code section 43830(g) provides an exemption for gasoline blends containing 10 percent ethanol from the ARB's summertime RVP standard of 7.0 psi. This exemption is eliminated if the ARB determines on the basis of independently verifiable automobile exhaust and evaporative emission tests performed on a representative fleet of automobiles, that the ethanol blend would result in a net increase in the ozone forming potential of the total emissions, excluding emissions of oxides of nitrogen, when compared to the total emissions, excluding emissions of oxides of nitrogen, from the same automobile fleet using gasoline that meets all applicable specifications for CaRFG established by the state board.

B. Is the Staff's Analysis Consistent With the Health and Safety Code Section 43830(g) Requirements?

1. Have the Appropriate Ethanol and Non-Ethanol Gasolines Been Compared?

Health and Safety Code section 43830(g) calls for the ARB to compare the ozone-forming potential of the total emissions resulting from "any blend of gasoline of at least 10 percent ethyl alcohol" that is exempt from the Board's RVP standard against the ozone-forming potential of the total emissions resulting from "gasoline that meets all applicable specifications for CaRFG established by the state board." The most appropriate fully complying gasoline to be used in the comparison would be one that is blended to be as close as possible to all of the flat limits in the CaRFG regulations, and which contains 2.0 wt.% oxygen using MTBE, the oxygenate in most widespread use in California. Eleven volume percent MTBE is added to gasoline to achieve a 2.0 wt.% oxygen content.

The most appropriate elevated RVP gasoline with ethanol to be evaluated in the comparison would be one in which 10 percent ethanol is added to the same base gasoline as was used in making the MTBE gasoline. The base gasoline is produced so that it meets the specifications for other regulated properties such as sulfur content after it is "diluted" by the 11 percent MTBE, and roughly the same dilutive effect occurs when 10 percent ethanol is added instead. If elevated RVP gasoline containing 10 percent ethanol were to be supplied commercially under the RVP exemption, one would expect ethanol to be blended with the same base gasoline as used in making gasoline blended with MTBE. The two gasolines compared in the ARB test program were approved by the Workgroup and meet these criteria.

2. Is the Proposed Determination Based on Independently Verifiable Automobile Exhaust and Evaporative Emission Tests?

The ARB established the Ethanol Workgroup to assist in defining the scope of the program. Based on input of the Workgroup, a test protocol was prepared and made available for the Workgroup's review. Once approved by the Workgroup, staff used the test protocol to conduct the test program. Both exhaust and evaporative emission tests were conducted. The steps taken in conducting the emission tests and analyzing the data were fully documented. The staff made the preliminary test data available to the Workgroup as they became available. The final test data were made available to the Workgroup and other interested parties for review on May 27, 1998. On July 15, 1998, staff met with the Workgroup to review the data and present staff's preliminary assessment of the test data. On October 22, 1998, staff presented the revised draft to the Workgroup for final comment.

Given the careful documentation of the test program and the confirmation from other test programs, the staff believes that the exhaust and evaporative emissions tests are independently verifiable.

The four studies reviewed by the staff that contain information on the speciated hydrocarbons are all published. Those studies were all reviewed and the data was subjected to established quality assurance and quality control standards prior to publication. The Auto/Oil Research program in particular is considered one of the most extensive and well designed programs conducted to date. The studies conducted by ATL (for ARB) were reviewed and approved by the ARB's Research Screening Committee. These data are independently verifiable and involved a wide cross section of motor vehicles.

3. Is the Vehicle Test Fleet Representative?

The test vehicles represent vehicles with emission control technologies found in a large segment of the California vehicle fleet. The vehicles tested have TWCs and fuel injection. All vehicles had evaporative control systems consisting of a vapor canister, a vapor line from the fuel tank to the canister, and a purge line from the canister to the intake manifold. These emission control technologies are found in model-year vehicles 1986 and newer. Three-way catalysts were introduced in 1981 and by 1986 almost all vehicles had TWC. The test vehicles are representative of normal and moderate emitting vehicles with TWC and fuel injection, and similar vehicles that are higher emitting due to non-optimal emission control systems but are not considered in disrepair.

The categories of vehicles represented by the test vehicles account for an estimated 70 percent of the vehicle miles traveled for 1998. As shown in Table VI-1, these vehicles account for a significant portion of the total estimated light-duty motor vehicle emissions inventory for 1998.

Table VI-1
Estimated Percent of Total Light-Duty Vehicle Emissions
(1986 and Newer Model Year Vehicles with TWC and Fuel Injection)

Reactive Organic Gas (ROG)	32 percent
Carbon Monoxide (CO)	42 percent
Oxides of Nitrogen (NOx)	48 percent

Additionally, there is strong evidence that older vehicles not included in the ARB test program directionally respond to oxygen and RVP in the same way as the test fleet, and similarly experience increases in ozone forming potential from elevated RVP gasoline containing ethanol. The available data on exhaust and evaporative emissions from older vehicles show that the small benefit in exhaust emissions due to the higher oxygen content is not sufficient to overcome the large increase in evaporative emissions. The Auto/Oil research program, the API study, and the ARB/ATL Low Oxygenates and Phase 1 Phase 2 test programs all tested older vehicles. Older vehicles have less sophisticated evaporative control systems, and the impact of higher RVP is thus likely to be proportionally equal or greater than the vehicles tested in our program. These studies demonstrate that increasing RVP will increase evaporative emissions in older vehicles. The studies also show that adding oxygen will reduce CO emissions but increase NOx emissions in older vehicles. Oxygen also appears to reduce exhaust hydrocarbons in older vehicles but not enough to offset the increase in evaporative emissions from an increase in RVP by 1 psi.

Vehicles considered "high emitters," which are vehicles that generally have faulty emission control systems and make a significant and disproportionate contribution to vehicle emissions, were not tested for several reasons. First, these vehicles have highly variable emissions from test to test on the same fuel. Thus it is difficult to detect fuel effects in such highly unstable vehicles.[10] This problem is particularly important where the emission difference due to the fuel is small, as can be the case where the fuels are similar. Even though the emissions change from such vehicles can be large, these changes are often due to the changes in vehicle performance from test to test rather than to the fuel. When the vehicle effect is accounted for, these vehicles would respond like normal emitting vehicles. Second, procurement and testing of a fleet that contains all current technologies and the appropriate mix of normal and high emitters would require a test program that greatly exceeds available time and resources.

Assuming that there is a favorable exhaust emissions response to the 10 percent ethanol, the higher RVP 10 percent ethanol blend would still increase evaporative emissions in high emitters similar to the increases exhibited in the ARB test program. Given that the evaporative emissions difference between the elevated RVP ethanol blend and the complying blend are much larger than

[10] Auto/Oil Air Quality Improvement Research Program Technical Bulletin No. 11: A Study of Fuel Effects on Emissions From High Emitting Vehicles, 1992

the exhaust emissions difference, in the case of high emitters the evaporative emissions would overwhelm exhaust resulting in an overall increase in emissions and associated ozone forming potential.

4. Is the Use of the Carter Maximum Incremental Reactivity Appropriate to Determine Ozone Forming Potential?

The ozone forming potential for the two fuels were determined using a reactivity adjusted emissions analysis. We used the Carter maximum incremental reactivity (MIR) scale to determine the ozone forming potential of the emissions measured. This scale applies an individual reactivity value to each species of nonmethane organic gas (NMOG) measured in the exhaust and evaporative emissions from the vehicles. NMOG includes oxygenated hydrocarbons that are typically not accounted for in a hydrocarbon standard. The individual MIR values were approved by the Board *[References 31 and 32]* for use in the test procedures used to account for the relative reactivity of fuel-related emissions in the ARB's low-emission vehicle program. The MIR values have been determined from atmospheric conditions when controlling hydrocarbons have the greatest impact on ozone formation.

The results of the reactivity adjusted emissions analysis show that there is an increase in the ozone forming potential for the elevated RVP ethanol blend compared to the complying blend. If the results of this analysis were evaluated using an Urban Airshed Model, the model would predict an increase in ozone concentrations from the use of elevated RVP ethanol blends. The Urban Airshed Model analysis considers many factors such as the emissions rate, time of the emissions, and meteorological conditions. In general, if the mass emission rate increases, the predicted ozone concentrations will increase. Likewise, if the mass of the reactivity adjusted emissions increases, the predicted ozone concentrations will also increase.

VII. ENVIRONMENTAL IMPACTS OF THE PROPOSED DETERMINATION

A. Impact on Air Quality

If the Board does not make the proposed HSC section 43830(g) determination, then gasoline containing 10 percent ethanol would be exempt from the RVP standard in the CaRFG regulations. The exemption could be used only if the Board amends the CaRFG regulations so that Predictive Model alternative formulations are allowed to have up to 3.5 wt.% oxygen. The staff's assessment in this report demonstrates that the use of elevated RVP gasoline containing 10 percent ethanol and otherwise meeting the CaRFG requirements would result in an increase in mass hydrocarbon emissions and associated ozone forming potential. The overall increase in emissions and ozone forming potential would depend on the market share attained for elevated RVP gasoline containing 10 percent ethanol. The use of the RVP exemption would be constrained by the fact that the federal RFG regulations, which apply to approximately 70 percent of the gasoline sold in California, do not provide for special RVP treatment for gasoline containing ethanol. If the Board makes the proposed determination, the emission benefits associated with the 7.0 psi RVP standard in the CaRFG regulations would be maintained.

B. Impact on Water Quality

Making the proposed determination would not result in a change to the current usage patterns of ethanol and MTBE in gasoline. If the Board does not make the proposed determination and increases the cap limit for oxygen to 3.5 wt.%, the existence of the RVP exemption would under some circumstances encourage the substitution of ethanol for MTBE in California summertime gasoline. A reduction in the use of MTBE could reduce the potential for MTBE contamination from gasoline leaking from storage tanks and pipelines.

Oxygenates are more soluble in water than are the hydrocarbon species in gasoline. Therefore, when gasoline leaks underground into an aquifer or enters a lake (e.g., in two-stroke engine exhaust), the oxygenate mixes with the water to a greater extent than does the rest of the gasoline. Whatever replaces the MTBE in gasoline could be less soluble than MTBE in water (e.g., aromatic hydrocarbons) or more soluble (e.g., ethanol) and would be present in any future leaks of gasoline.

MTBE has little tendency to adsorb to soil, so that when gasoline with MTBE leaks into an aquifer, it can move from the point of leakage faster than does the rest of the gasoline. Alternative substitute materials could be less mobile. It should be noted that the ultimate magnitude and health consequences due to MTBE in ground water are still not known.

The primary release of MTBE into groundwater is from leaking underground pipes and storage tanks used in the transportation and storage of MTBE-containing gasoline. Thus, the prevention of gasoline leaks is the basic remedy to reduce ground and surface water contamination. The rate of leaks and the number of leaking tanks is expected to be reduced greatly, as the underground storage tank replacement program is fully implemented. To the extent that the proposed regulations result in a reduction in the use of oxygenates (or substitution of ethanol for MTBE), they would lessen, to a small degree, the threat of ground and surface water contamination. However, the effect of the proposed regulations on the overall use of oxygenates, in the near term, is expected to be small because refiners are unlikely to reduce the use of oxygenates due to federal requirements. Also, the replacement of MTBE by the use of ethanol is likely to be limited because of ethanol's limited supply and state and federal limits on volatility.

Recreational boating is thought to be the primary source of MTBE in surface water. In addition, atmospheric MTBE can dissolve in rainwater and enter surface water through storm water runoff. However, both recreational boating and atmospheric sources are believed to result in low concentrations of MTBE in water relative to point sources such as underground storage tanks.

Less importation of MTBE into California, which is by water, could reduce the risk of a marine spill of MTBE. Increased importation of ethanol could increase the risk of a major spill of ethanol.

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