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Technical Support Document:

Analysis of California's Request for Waiver of the Reformulated Gasoline Oxygen Content Requirement for California Covered Areas

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Transportation and Regional Programs Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Docket A-2000-10
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A. Governor Davis' April 12, 1999 petition for waiver

In a letter dated April 12, 1999 from California Governor Gray Davis to Administrator Browner (Filed in docket A-2000-10, document number II.D.-1; also available at http://www.arb.ca.gov/cbg/Oxy/wav/041299.pdf), California requested a waiver from the federal oxygen requirement for reformulated gasoline, under Section 211(k)(2)(B) of the Clean Air Act (CAA or the Act). EPA may waive the oxygen mandate, in whole or in part, "...upon a determination by the Administrator that compliance with such requirement would prevent or interfere with the attainment by the area of a national primary ambient air quality standard ." CAA § 211(k)(2)(B). The April 12, 1999 submittal stated that "the ARB will be revising its CaRFG program this year, and continuing the oxygen mandate will make it more difficult to maintain the emission reductions benefits needed for California's SIP." The submittal did not, however, contain the technical analysis to support the State's conclusion that the oxygen requirement would prevent or interfere with the attainment of the National Ambient Air Quality Standards (NAAQS) in California. As such, the Agency believed that the request submitted by California on April 12, 1999 did not provide enough detail about the underlying analyses upon which the request was premised to allow EPA to make a careful and fully informed decision on the request.

B. California Air Resources Board (CARB) July 9, 1999 submittal

CARB provided a more detailed analysis in a submittal to EPA dated July 9, 1999. (Filed in docket A-2000-10, document number II.D.-2; also available at http://www.arb.ca.gov/cbg/Oxy/wav/070999.pdf) . CARB attempted to demonstrate that an additional 1.5 percent reduction in NOx reductions could be achieved with zero oxygen in California's gasoline. CARB also claimed that it would be impossible to achieve the same level of additional NOx reduction with the 2.0 weight percent oxygen requirement in place. CARB argued that additional NOx reductions are needed in order for California to attain ozone and PM NAAQS. CARB concluded that in light of these findings, the federal oxygen content requirement interferes with attainment of both the ozone and PM NAAQS. CARB based its argument on the use of its Phase 2 Predictive Model[1]. The reductions in NOx under both the 2.0 weight percent oxygen and non-oxygen scenarios were based on reduction of sulfur in the fuel and the relationship between NOx formation and oxygen level in the fuel. No other parameters were discussed in this submittal.

EPA responded to CARB's July 9, 1999 submittal on August 6, 1999, with a letter to CARB, (Filed in docket A-2000-10 as document number II.C.-2) which included the following questions:

- What other fuel parameters besides reduction of sulfur has CARB considered in evaluating the extent to which NOx can be reduced with 2.0 weight percent oxygen in gasoline?

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[1] The Predictive Model is a spreadsheet model developed by CARB as a tool for determining fuel compliance with California's emission requirements. The model estimates the emissions corresponding with the specific fuel parameters of a candidate fuel. The Phase 2 Predictive Model is the fuel certification model developed in conjunction with California's Phase 2 RFG program.

- Given CARB's statement that a waiver of the summertime oxygen requirement would be appropriate, we questioned whether elimination of the minimum oxygen requirement of 1.5 weight percent might be an acceptable scenario in lieu of a waiver.
- In light of CARB's stated concerns that the oxygen mandate would prevent the maximum NOx reduction possible via its Phase 3 California reformulated gasoline (CaRFG3) regulations (which at that time had not been promulgated), what assumptions were made about the CaRFG3 fuel in the analysis?

C. CARB September 20, 1999 response to EPA questions

CARB responded to EPA's August 6, 1999 letter in a letter dated September 20, 1999. (Filed in docket A-2000-10; document number II.D.-3; also available at http://www.arb.ca.gov/cbg/Oxy/wav/092099.pdf). CARB's July 20, 1999 response to our questions indicated that RVP and sulfur were the two key parameters in setting new baseline fuel specifications "because emissions are most sensitive to these parameters and when either is reduced, emissions of regulated pollutants go down." CARB claimed that if the other properties were changed, emissions of one or more pollutants would decrease (usually to a much smaller degree) but emissions of at least one other pollutant would increase. CARB concluded that these other parameters are much less useful in making complying fuels with the needed NOx reductions.

With respect to the assumptions made for the CaRFG3 fuel in its analysis, CARB stated that "there was no need to assume anything for Phase 3 CaRFG other than there still exists a need

for further reductions in emissions." CARB also claimed that "the ability to reduce NOx and evaporative hydrocarbon emissions is greater without oxygen" independent of which fuel properties are varied. This particular hypothesis was addressed more fully in a subsequent analysis included in a December 24, 1999 submittal, discussed in I.D. below.

CARB's September 20 response also indicated that elimination of the 1.5 weight percent oxygen minimum would have no effect on the conclusions reached in its July 9 analysis, stating that under such a scenario the oxygen content in RFG in the summer months would average about 1.25 weight percent oxygen, and would provide very little flexibility to produce non-oxygenated RFG. CARB's response described the effect of a waiver on California refiners to produce non-oxygenated RFG but provided no analysis of whether greater[?] NOx emission reductions could be more easily achieved with 1.25 weight percent oxygen versus 2.0 weight percent.

In mid-October, 1999, CARB staff provided new information. CARB staff informed us that the general assumptions stated in CARB's July 9, 1999 technical submittal to EPA were no longer applicable. Specifically, in the July 9, 1999 submittal, CARB stated that an additional 1.5 percent reduction in NOx reductions could be obtained with zero oxygen in the fuel and that it would be impossible to achieve the same level of additional NOx reduction with 2.0 weight percent oxygen in the fuel. In mid-October CARB staff now claimed that the Beta version of their Predictive Model for use with the Phase 3 CaRFG (which CARB had not yet promulgated) showed that California's in-use fuel in fact produced more NOx reductions than the additional 1.5 percent they suggested could only be achieved with zero oxygen, and that their proposed Phase 3 CaRFG would achieve even more. CARB further indicated that additional NOx

reductions would be achieved by the Phase 3 CaRFG if the oxygen content requirement were removed, and that such reductions were necessary in order to meet ozone and PM NAAQS in California. Because, at that point, the assumptions supporting their argument as stated in the July 9, 1999 submittal were no longer applicable, EPA was not in a position to further evaluate California's waiver request. In early November, CARB staff informed EPA that they were producing an analysis to support the approach described in mid-October. They agreed that EPA action on the waiver request would be delayed, pending receipt and review of the new analysis from CARB. Given these developments, we did not respond to CARB's September 20, 1999 response to our questions.

D. CARB December 24, 1999 submittal

CARB submitted additional material in support of California's request for a waiver by letter dated December 24, 1999. (Filed in docket A-2000-10, document number II.D.-6; also available at http://www.arb.ca.gov/cbg/Oxy/wav/122499.pdf). The material contained the results of a computer simulation using their recently modified Predictive Model (the CaRFG3 Predictive Model, or PM3). The computer simulation evaluated a large number of complying fuels containing 2 percent oxygen by weight versus a similarly large number of complying fuels containing zero oxygen.

After our review of the December 24, 1999 submittal, we determined that we needed additional information from CARB to conduct a thorough technical review of the request. EPA requested this additional information in a January 20, 2000 memorandum from Robert Perciasepe, Assistant Administrator for Air and Radiation to Winston Hickox, Secretary California Environmental Protection Agency, as follows:

1) An explanation of the difference in the effect of fuel oxygen on NOx emissions between Phase 2 and Phase 3 of CARB's Predictive Model;

2) A demonstration that the CO increases associated with reductions in oxygen in gasoline would not counterbalance NOx decreases resulting from the waiver, if granted; and

3) A demonstration that the ethanol commingling effect would not counterbalance the NOx decreases resulting from the waiver, if granted[2].

Subsequent to the above memo being sent, EPA staff met with CARB staff on January 24 and 25, 2000 regarding these and other issues. CARB indicated at the meeting that it would provide additional information to EPA. CARB provided this information to EPA in a submittal dated February 7, 2000.

E. CARB February 7, 2000 submittal

In a submittal dated February 7, 2000, (filed in docket A-2000-10, document numbers II.D.-20 and 21; also available at http://www.arb.ca.gov/cbg/Oxy/wav/029799.pdf and http://www.arb.ca.gov/cbg/Oxy/wav/029799at.pdf) CARB provided EPA with information on six topics:

1) Comparison of CaRFG3 Predictive Model to the EPA's Complex Model

(2) Identification of the NOx benefits representative of non-oxygenated gasoline and ethanol RFG blends produced to meet the CaRFG3 standards

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[2] Commingling refers to the mixing of non-oxygenated RFG with ethanol RFG blends in the gas tanks of consumer's automobiles. Even if a waiver were granted, there would still be ethanol RFG blends, so that commingling would occur. Since the presence of ethanol causes an increase in the volatility of the gasoline (as measured by the Reid Vapor Pressure or RVP), such commingling would contribute to an increase in evaporative VOC emissions.

(3) Discussion of CO, hydrocarbons and NOx issues

(4) ARB's efforts to address commingling effects

(5) Additional information on the simulation analysis of future gasolines produced to comply with CaRFG3 specifications

(6) Sensitivity analysis to evaluate the effect of not including off-road emissions in the CaRFG3 Predictive Model.

The Agency then began an independent evaluation of the data and modeling, as well as the other information submitted by California in support of its request for a waiver from the federal RFG oxygen content requirement.

II. SUMMARY OF CALIFORNIA'S WAIVER REQUEST

California's analysis in support of its waiver request rests first on CARB's assertion that additional NOx reductions are needed in California. Specifically, CARB claims that the South Coast Air Quality Management District (SCAQMD) and Sacramento Metropolitan Air Quality Management District (SMAQMD) need additional NOx reductions to meet a schedule of NOx reductions associated with attainment of the National Ambient Air Quality Standards (NAAQS) for ozone and particulate matter. Specifically, in the SCAQMD, CARB claims that there is a shortfall of 11 tons/day of the NOx reductions needed to meet the State's 2005 ozone SIP milestone for the SCAQMD. (SCAQMD must meet the ozone NAAQS by 2010 and the PM10 standard by 2006). In the Sacramento RFG area, there is a 4 tons/day shortfall of the NOx reductions needed for that area to achieve attainment for ozone in 2005 (its attainment year).

Having addressed the need for additional NOx reductions in the SCAQMD and SMAQMD regions, CARB then claims that without the oxygen requirement, CaRFG3 would achieve greater NOx reductions . This assertion is based on CARB's evaluation of several factors, including the relationship between gasoline oxygen content and NOx emissions; the likely composition of California's gasoline with and without a waiver; the impact of a waiver on vehicle emissions other than NOx; and the impact of additional emissions from commingling of ethanol-oxygenated and non-oxygenated gasoline in vehicle gas tanks.

CARB's submittal contained the following analyses and arguments:

1) A comparison of CaRFG3 Predictive Model to the EPA's Complex Model

CARB's Predictive Model shows that NOx emissions increase as a function of oxygen in the fuel, which as discussed above is CARB's main argument in support of its claim that the oxygen requirement interfered with or prevented attainment of the NAAQS for ozone and particulate matter (PM). (CARB's analysis and our subsequent evaluation are discussed in further detail in Section III.A). CARB felt that its Predictive Model was an appropriate tool to use because it felt that the statistical procedures and software tools used to develop its model were more current than those used for the Complex Model. Moreover, the available body of emissions test data had expanded since the Complex Model was developed (especially data on high-emitting vehicles and newer-technology vehicles). Compared to CARB's Predictive Model developed for Phase 2 RFG (PM2), CARB stated that the Phase 3 Predictive Model (PM3) displayed a steeper NOx/oxygen response as a result of dropping the RVP-by-oxygen term which the earlier version of the software had erroneously included.

(2) Identification of the NOx benefits representative of non-oxygenated gasoline and ethanol RFG blends produced to meet the CaRFG3 standards

CARB evaluated the factors it felt were likely to influence how refiners would make gasoline to comply with the California Phase 3 RFG (CaRFG3) regulations for California's federal RFG areas . Because of the California's ban on MTBE in gasoline (which takes effect in 2003), CARB limited its analysis to how refiners would produce RFG with and without a waiver using ethanol. CARB relied on staff assessment of likely CaRFG3 properties as well as on prediction of fuel formulations from a study conducted by MathPro for the California Energy

Commission (CEC). Analysis of California Phase 3 RFG Standards", MathPro Inc., December 7, 1999 (available at http://www.arb.ca.gov/regact/carfg3/appp.pdf.). The refinery modeling that MathPro conducted for the CEC modeled the composition and production cost of gasolines meeting the proposed CaRFG3 regulations. CARB used estimates of formulations for non-oxygenated and oxygenated fuels as inputs to CARB's Predictive Model to estimate the reduction in NOx associated with elimination of oxygen in gasoline, as well as changes in exhaust and evaporative VOC. (CARB's analysis and our subsequent analyses, including refinery modeling that we had MathPro conduct, are discussed in greater detail in Section III.B). Based on the reduction in NOx emissions estimated by CARB's Predictive Model, CARB then applied these emissions using its mobile emission model EMFAC7G, and applied the result to the amount of Vehicle Mile Traveled in the federal RFG areas in California to calculate the difference in NOx emissions if a waiver were granted. CARB estimated that an additional 5 tons/day reduction in NOx in the South Coast Air Quality Management District (SCAQMD) would result from Phase III reformulated gasoline with zero percent oxygen relative to Phase III reformulated gasoline with oxygenate requirement. (See Docket A-2000-10, Document II-D-54.) These estimates reflect the emission reductions that would occur if the entire South Coast used oxygen-free Phase III gasoline; i.e., 100 percent market penetration.

In the Sacramento RFG area CARB estimated (using EMFAC7G) that an additional 1 ton/day of NOx would result from Phase III reformulated gasoline with zero percent oxygen relative to Phase III reformulated gasoline with oxygenate requirement. This again assumes 100 percent market penetration of non-oxygenated gasoline. (See Docket A-2000-10, Document II-D-54).

(3) Discussion of CO and VOC issues

CARB provided estimates of the increase in CO emissions associated with a waiver based on tests conducted using the Federal Test Procedure (FTP) and included the effect of lower sulfur and T50. (CARB's procedure is documented in Appendix G of the staff report for its CaRFG3 rule, available at http://www.arb.ca.gov/regact/carfg3/appg.pdf.) CARB concluded that on average, CO would increase 5.8 percent (per percent oxygen reduced) for vehicles of model years 1981-1985, 4.99 percent (per percent oxygen reduced) for model year vehicles 1986-1990, 1.39 percent (per percent oxygen reduced) for model year vehicles 1991 to 1995, and zero percent for model year vehicles later than 1995. However, CARB also assumes that reductions in sulfur and T50 would occur to offset any increase in exhaust HC resulting from oxygen removal, and that these reductions would also lower CO emissions, partially mitigating the CO increase due to oxygen removal. Based on this procedure, CARB estimated an increase of 133 tons/day of CO in covered RFG areas in California.

CARB also estimated the reduction in VOC emissions with a waiver, due to the decrease in ethanol use and the associated reduction in permeation losses (this is discussed in further detail in Section III.C.1.e.) Permeation losses are the evaporative VOC emissions that escape through soft fuel system components (such as hoses and seals), and that are associated with the use of ethanol in gasoline. CARB estimated that the difference in evaporative emissions (due to permeation losses) between non-oxygenated gasoline and gasoline with 10 volume percent ethanol (2.0 weight percent oxygen) is about 13 tons/day for all federal RFG areas in California, assuming 100 percent penetration of non-oxygenated fuels. Using relative reactivity factors, CARB argued that its estimated 13 ton/day reduction in evaporative VOC (from the decrease in

permeation losses) would offset its estimated 133 ton/day increase in CO emissions. (CARB's analysis and our subsequent evaluation are discussed in further detail in Sections III.C.1, III.C.3 and III.D.)

(4) CARB's discussion of commingling effects

With a waiver VOC emissions would increase when non-oxygenated and ethanol-oxygenated RFG commingled, or mixed together in vehicle fuel tanks). CARB estimated that the ethanol commingling effect would result in an estimated 0.1 psi increase in the actual RVP of gasoline in vehicle tanks in California's RFG covered areas using an approach described in further detail in Section III.C.2. To compensate for any loss in air quality benefits in the event that a waiver were granted, CARB incorporated into the CaRFG3 regulations a reduction of the flat limit for RVP from 7.0 psi to 6.9 psi.

(5) Simulation analysis of future gasolines produced to comply with CaRFG3 specifications

CARB conducted a computer simulation using their recently modified Predictive Model (the CaRFG3 Predictive Model, or PM3) to evaluate a large number of complying fuels containing 2 percent oxygen by weight versus a similarly large number of complying fuels containing zero oxygen.

CARB varied the values of the aromatics, olefins, sulfur, T50, T90, and benzene fuel parameters of each of the two sets of complying fuels (i.e., 2 weight percent oxygen fuels and zero percent oxygen fuels) between the limits shown in Table 1 below:

Table 1. Boundary values for fuel properties in CARB's simulation analysis

	Lower Bound	Upper Bound	Increment
Aromatics	15	35	5
Olefins	0	10	1
Sulfur	0	60	2
T50	175	220	2.5
T90	285	330	2.5
Benzene	0.1	1.1	0.1

CARB generated over 10 million combinations of fuel properties within the bounds in Table 1, and using the PM3 identified the subset of these hypothetical fuels which would comply with CARB's standards for its Phase 3 CaRFG.

CARB's simulation analysis showed that on average among the large number of complying formulations, the additional reduction in NOx associated with going from a 2 weight percent oxygen fuel to a zero oxygen fuel is about 1.5 percent. On the basis of this simulation analysis CARB claimed that the reduction of NOx is greater without oxygen independent of which fuel properties are varied.

CARB's analysis indicates that at zero oxygen, 90 percent of the 3.2 fuels modeled and that comply with the CaRFG3 regulations would have NOx reductions of -0.7 percent; at 2 percent oxygen by weight, 90 percent of the 3.5 million fuels modeled and that comply with the CaRFG3 regulations would have NOx reductions of -0.2 percent. The average NOx reduction for a complying non-oxygenated fuel was 4.2 percent; for a complying fuel at 2 percent oxygen by weight, the average NOx reduction was 2.4 percent. CARB argued that its analysis verifies

the consistency of the NOx reduction associated with reducing oxygen content in CaRFG3 from 2 to zero percent by weight. (CARB's analysis is discussed briefly in the context of refinery modeling that MathPro completed for EPA in Section III.B.)

(6) Sensitivity analysis to evaluate the effect of not including off-road emissions in the CaRFG3 Predictive Model.

CARB based emission changes due to non-oxygenated fuels solely on the use of its Predictive Model. The Predictive Model does not include off-road vehicle emissions data; it was built solely from on-road vehicle emission data and was intended to represent only on-road emissions. CARB argues that off-road vehicles emit a disproportionate share of gasoline emissions because they have remained uncontrolled until recently. CARB further argues that recent more stringent emissions standards on these engines should lead to the use of more sophisticated emissions control technology such as advanced fuel control systems, post combustion controls, and evaporative controls. Finally, it asserts that as the number of newer off-road vehicles increase, the effect of fuel property changes on emissions will be more like on-road automobile emissions. CARB concluded that it was appropriate to exclude off-road emissions from its analysis.

CARB conducted a sensitivity analysis using its Predictive Model, to examine the effects of CaRFG3 fuel on emissions from older on-road vehicles (pre-1981) which CARB terms "Tech 3" vehicles. Through this analysis CARB essentially used the PM3 Tech 3 vehicle data-set to represent off-road vehicles. CARB computed NOx, VOC, and CO emission from oxygenated and non-oxygenated CaRFG3 fuels for these vehicles, and weighted the emission changes using

relative reactivity factors. Based on its analysis, CARB concluded that any errors from not including the off-road emissions in its analysis of fuel oxygen effects were relatively small and would not affect its conclusions about the impact of a waiver on emissions in California's RFG areas. (CARB's analysis and our subsequent evaluation are discussed in further detail in Section III.C.4).

III. EPA'S EVALUATION OF CALIFORNIA'S PETITION

The Clean Air Act requires that, in order to waive the federal RFG oxygen requirement, EPA must determine that compliance with the requirement prevents or interferes with attainment of a relevant NAAQS. The key question before the agency therefore involves the air quality impacts of a waiver for the relevant NAAQS.

To address the air quality impact, it is critical to consider both the potential changes in gasoline quality which could occur if a waiver were granted and the potential emissions impacts of these changes. All relevant categories of emissions should reasonably be considered. This information is needed to evaluate the impacts of a waiver on each applicable NAAQS. This section provides details on our evaluation of California's petition.

Our evaluation of California's request for a waiver contained three critical areas for review:

(1) NOx, VOC and CO emissions vary directly with the amount of oxygen in the fuel.

CARB's predictive model shows that NOx varies directly with the amount of oxygen in the fuel. We audited CARB's Phase 3 Predictive Model (PM3), and created our own predictive

model to evaluate the effect of fuel oxygen and other properties on NOx.[3] Our investigation generally verified CARB's assertions. (See Section III.A) EPA also prepared a model for exhaust VOC, and used pre-existing models for evaporative VOC, permeation losses, and commingling. We looked at both on-road and off-road emissions.

(2) Refiners will actually produce and market significant amounts of oxygenated gasoline in the relevant RFG areas with a waiver (See Section III.B)

In a waiver scenario, it is likely that a mix of ethanol oxygenated and non-oxygenated CaRFG3 would be produced, but a performance benefit may or may not apply to the non-oxygenated portion of the market relative to the oxygenated portion. Any such benefit would depend on the fuel properties associated with both the non-oxygenated portion of the gasoline pool and the oxygenated portion of the pool. To assess likely market penetration and how fuel would likely be formulated in a waiver scenario, we contracted with MathPro to conduct refinery modeling. Based on the predicted fuel formulations and market penetrations for non-oxygenated fuels, we were then able to estimate emission changes resulting from a waiver of the oxygen requirement.

(3) The overall emissions effects of a waiver indicate a reduction in NOx, an increase in CO and significant uncertainty about VOCs.

We evaluated the emission effects of the various scenarios from the refinery modeling for NOx, VOCs and CO. The results indicate a reduction in NOx, an increase in CO, and significant

[3] Strictly speaking, these models (CARB's and EPA's) are all intended to predict NOx emissions as a function of the formulation of the fuel being evaluated. Removal of oxygen from California RFG would necessarily bring about changes in fuel properties other than oxygen. Any model used to analyze the effects of removing oxygen from all or part of the fuel would have to be capable of examining the joint effects of changes in all of the fuel properties, even though some properties might change little or not at all.

uncertainty about the overall change in VOCs. The evidence is not at all clear what the overall effect of the emissions changes from a waiver would have on ozone.

A. Evaluation of the oxygen content-NOx emission relationship

1. CARB's Phase 3 Predictive Model (PM3)

CARB developed the predictive model to allow evaluation of gasoline specifications, or "recipes", as alternatives to the flat and average property limits on gasoline specifications in California's regulations. California's regulations contain limits on specifications for eight fuel parameters; RVP, sulfur, benzene, aromatic hydrocarbons, olefins, oxygen, T50 and T90. The limits are either a flat per gallon limit, or an average limit with an accompanying per gallon cap. Refiners of California reformulated gasoline may comply with California's regulatory requirements by producing gasoline that meets these flat or averaging limit specifications. Refiners may also specify alternative limit values for these properties if they demonstrate using the predictive model that their alternative recipe produces equivalent (i.e., no more than 0.04 percent higher) or better emissions than the reference specifications for hydrocarbons, oxides of nitrogen and potency-weighted toxics. A prior version of the predictive model was available for use with California's Phase 2 RFG program; the PM3 model is an updated version for use with California's Phase 3 program.

The predictive model consists of a number of sub-models which relate gasoline properties to changes in emissions. Each of the exhaust sub-models was derived by regression analysis of the predictive model database. This database of emission test results and fuel property information was assembled from a number of separate studies which investigated the effects of fuel properties on emissions. The Phase 3 model includes eighteen exhaust sub-models. These

sub-models represent six pollutants (NOx, HC, benzene,1,3 butadiene, formaldehyde and acetaldehyde) in each of three technology classes. These technology classes are Tech 3 (model years 1981-85), Tech 4 (model years 1986-1995) and Tech 5 (1996 and newer).[4] The predictive model contains technology class weighting factors to combine emissions difference predictions for a given pollutant into a single prediction, representative of a portion of the California fleet. The Phase 3 predictive model weights for NOx and exhaust HC represent, for each of the two pollutants, the fractional contribution of exhaust emissions from on-road gasoline fueled vehicles in a particular Tech class to the total contribution of exhaust emissions from these three Tech classes in year 2005. These factors were calculated using information in California's mobile source emissions model EMFAC/BURDEN7G.

The Phase 3 predictive model differs significantly from the Phase 2 model because of various updates and additions, some of which are described below. A substantial amount of new data, mostly from 1986 and newer vehicles, were added to the database. Consequently, CARB generated new regression equations to represent Tech 3 and Tech 4 vehicles. CARB staff also determined that there were sufficient data to model the Tech 5 class, which was not represented as a separate group in the Phase 2 model. The Tech 5 class represents vehicles, including low emission vehicles, with more advanced emission control technology than Tech 4. The Phase 3 model also adds an evaporative emissions compliance option which contains a carbon monoxide reduction credit. The evaporative emissions option allows refiners to determine hydrocarbon emissions equivalency based on a combination of exhaust and evaporative emissions. The CO

[4] For development of the phase 3 model regression equations, data from model year 1994 and newer vehicles in the predictive model database were classified as Tech 5. The Tech 5 category and emission weighting in the model represents 1996 and newer vehicles.

credit, a function of oxygen content (for oxygen greater than 2 percent by weight), recognizes the ozone forming capacity of CO. If the evaporative option is used, exhaust HC, evaporative HC and the credit for CO reduction are combined using a formula that considers relative reactivity and emissions fractions. A refiner's candidate specification is acceptable only if the model shows equivalent or better ozone formation than the reference specification.

2. Description and comparison of available models for predicting NOx emissions

California relied on the Phase 3 predictive model to demonstrate that removal of the oxygen requirement would likely result in further reductions in NOx emissions beyond those that would be achieved with oxygenated CaRFG3. Consequently, consideration of the NOx/oxygen relationship in the Phase 3 predictive model is an essential element of our evaluation of California's waiver request. We have examined the response of this model to changes in oxygen content. We have also compared this response to that of the Phase 2 predictive model, and to EPA's Complex Model. EPA's Complex Model is used to determine compliance with the emissions performance requirements for federal RFG. It compares the emissions performance of a candidate fuel to a baseline fuel, for common baseline vehicle technology. The baseline fuel and the baseline vehicle technology represent 1990 fuels and the vehicle technology used in model year 1990 light-duty vehicles. See CAA §211(k)(3)(10).

The following table summarizes responses to a change from two-percent oxygen to zero oxygen in a recipe where other fuel properties are held constant at the phase 3 flat limits. These emission changes are expressed as a percent change from the NOx emissions at the two-percent level, with a negative number indicating a decrease in emissions. Table 2 shows responses for both the entire phase 2 predictive model (PM2) and the entire phase 3 predictive model (PM3),

as well as for each component of the two predictive models. Only the composite Phase II Complex Model result is shown. EPA's Complex Model, consistent with RFG provisions of the Clean Air Act, represents 1990 model year technology vehicles. The data used to develop the Complex Model, however, were not restricted to 1990 model year vehicles, and a substantial amount of data is common to the predictive model and Complex Model databases. Since the vehicles represented by the Complex Model fall within CARB's Tech 4 category, it may be more appropriate to compare the Tech 4 model, rather than the composite predictive model, to the Complex Model.

TABLE 2 Estimated Percent Change in NOx for Oxygen Content Change from 2% to 0% (Other properties at Ca Phase 3 flat limits)

Model	Percent Change (negative indicates decrease)
PM3 - Tech 3 only	-2.76
PM3 - Tech 4 only	-1.76
PM3 - Tech 5 only	-1.75
PM3- composite[5]	-1.88
PM2 - Tech 3 only	-2.28
PM2 - Tech 4 only	-0.14
PM2 - composite (see footnote 5)	-0.52
Phase II Complex Model (see footnote 5)	0.23

[5] Each of the composite models (including the Complex Model) is made up of separate technology group effects weighted by their respective proportional contributions to fleet NOx emissions at some point in time. Since the models were designed to represent different times, these composite effect levels are not directly comparable with each other. Each model was constructed using the best statistical methodology and software that was available, but there have been major improvements in the available statistical tools since the Phase II Complex Model was constructed.

It is apparent from Table 2 that some disparity exists among the models in the estimated direction and magnitude of the NOx response to changes in oxygen content, all else being constant. California's Phase 2 and Phase 3 models both indicate a NOx increase with increasing oxygen, however the Phase 3 model shows a much steeper response. The Complex Model, by contrast, predicts that NOx will decrease slightly as oxygen increases. It should be noted that the magnitude of the NOx response to oxygen, even as predicted by the Phase 3 model, is not large when compared to NOx emission differences between vehicles, or test-to-test variability in emissions. The small size of the oxygen effect on NOx emissions indicated in all of these models makes it difficult to detect statistically and to precisely quantify.

We can, however, identify some of the potential causes for differences in the NOx/oxygen response among these models, other than additions to available data. For example, the Complex Model contains separate equations for normal and high emitting vehicles, which are weighted by an estimated emissions fraction for each group. The normal emitter NOx equation indicates that NOx emissions increase as oxygen increases, while the high emitter equation indicates that NOx decreases as oxygen increases. The predictive models, both Phase 2 and Phase 3, do not model normal and high emitters separately.

The Complex Model was developed using a fixed effects statistical modeling approach. Both versions of the predictive model were developed using a mixed-effects statistical modeling approach, in which fuel effects were considered fixed and vehicle effects were considered random[6]. The statistical software available to develop the Phase 3 predictive model was a

[6] A "fixed effects" model of this kind makes no attempt to estimate the error introduced by sampling from some larger population of vehicles or fuels. The model just describes quantitatively the relationships among variables that are present in the dataset that was analyzed. A "mixed" model, as was used by CARB in both the Phase 2 and Phase 3 predictive models'

substantial improvement over that which was used to develop the Phase 2 model.[7] Consequently, according to CARB staff, an RVP-by-oxygen interaction term in the Tech 4 model was no longer statistically significant using the newer software, and was not included in the revised model. According to CARB staff, this term would not have been in the Phase 2 model had the newer software been available; thus the Phase 2 Tech 4 model would have looked much like the Phase 3 Tech 4 model.[8]

As can be seen from the above, the development of a model relating gasoline properties to emissions requires a number of decisions. For both the complex and predictive models, some of the most important decisions included the acceptance or rejection of data, treatment of high emitters, selection of statistical modeling methodology, inclusion or exclusion of certain terms during model development, and choice of a final model from alternative candidate models. These decisions cannot always be made solely by objective means, such as the application of a statistical test of significance. To a large extent, these modeling decisions require application of engineering judgement or consideration of limitations of computer hardware/software. Divergent

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construction, attempts to go beyond description of the available data to make statistical inference to some larger population from which the available data were sampled. In this case CARB treated the vehicle effects as random (assuming that the test vehicles were sampled from some larger fleet) while fuel effects were treated as "fixed" (assuming that all fuels of interest were represented in the data). Such a modeling approach makes it possible to estimate the probable error in modeled effects in a way that is not possible with a fixed effects model. The approach, moreover, improves the accuracy of the significance measures used to decide which terms to include in the model.

[7] The important difference was development of an improved algorithm for guiding a sequence of iterations. In the earlier version the iterative process came to a premature conclusion and slightly mis-estimated the explanatory power of certain terms.

[8] See January 24, 2000 memorandum from Win Setiawan, CARB, to Steve Brisby, Manager Fuels Section, CARB (in Docket A-2000-10, Document Number II.D.-18h).

decisions at different points in the model development process can clearly lead to substantially different final results.

In an attempt to resolve the uncertainty about the NOx/oxygen relationship, EPA staff and a consultant audited the process that CARB staff used to develop the Phase 3 predictive model. Additionally, we independently developed alternative models for NOx as a function of fuel properties for the Tech 4 vehicles. This work is described in the two sections that follow.

3. Audit and verification of PM3

We engaged in a several step process to evaluate and verify the oxygen-NOx effects projected by California's PM3. This process and its results are outlined below.

a. Handling of Vehicle Technology Groupings

In order to predict emissions for the entire vehicle fleet as a function of fuel characteristics, the Predictive Model must make predictions for each of the three major groups of vehicle technologies that make up the bulk of the vehicle fleet at present and for the immediate future. The Tech 3 group is not a significant part of the predictive model, since these vehicles contribute a rapidly shrinking proportion of fleet emissions as they are replaced and as the remaining vehicles drive fewer miles per year. The body of data for Tech 3 vehicles in CARB's Phase 2 and Phase 3 Predictive Models is quite similar. Tech 5 vehicles, on the other hand, constitute an increasing percentage of the overall vehicle fleet, but present a problem due to lack of data on the emissions effects of fuel changes. There are some test programs that have examined the NOx impact of varying fuel sulfur content for tech 5 vehicles, but there is very little information useful for examining the NOx emissions consequences of altering the oxygen content of gasoline.

CARB's Tech 5 modeling seems to have drawn heavily upon Tech 4 data, to which is added a small body of data on Tech 5 vehicles. EPA understands the difficulty of drawing conclusions in the absence of good relevant data. The changes to vehicle technology that give rise to the "Tech 5" designation[9], however, would seem to be at odds with CARB's implicit conclusion that these vehicles' NOx performance will be similar to that of the Tech 4 vehicles as oxygen is varied. This is a matter of judgment in the absence of a robust set of directly applicable data, but EPA believes that California gave too much weight to the older Tech 4data, resulting in a likely overestimation of the oxygen effect on NOx in Tech 5 vehicles, a technology grouping that will be an important fraction of the vehicle fleet by the year 2005. As explained in Section III.A.4, we took a very different approach in determining the effect of oxygen on the NOx emissions of Tech 5 vehicles.

b. The Dataset

EPA's contractor examined the dataset to verify that CARB correctly integrated the Complex Model dataset and the information from various other sources into its Phase 2 and Phase 3 analyses. No problems were found. We note the inclusion of a substantial body of additional data from vehicles identified as high-emitters, which we believe makes the dataset more representative of the actual California vehicle fleet.

Before analyzing the data, CARB removed observations made using fuels that would not ever be used in California. These specifications are described fully in the contractor's report (the

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[9] The computer systems and associated sensors typically used in Tech 5 vehicles exert more effective control over air/fuel ratios than is typically the case for Tech 4 vehicles. Since the emissions effects from adding oxygen to fuel results in large part from the "enleanment" effect of the additional oxygen, there is reason to believe that tech 5 vehicles should be less sensitive to fuel oxygen changes.

Audit)[10], but included among other things a restriction on oxygen content that removed data from fuels with oxygen in excess of 4 percent by weight. EPA staff and contractor agreed that these deletions were appropriate, given CARB's intent to specifically model California gasoline. Inclusion of data from fuels outside these bounds might distort the model and limit its ability to predict the emissions behavior of fuels that would actually be used in California. While these property limit restrictions did admit fuels with property values exceeding CARFG3 caps, they excluded fuels with property values exceeding those which would normally occur in conventional or reformulated gasoline (e.g. fuels with oxygen in excess of 4 percent by weight.) Automobile manufacturers would not be expected to design vehicles to operate with such fuels, and such fuels could produce unrepresentative emission results.

CARB also decided to remove data from certain "high influence" vehicles.[11] It is puzzling, however, that CARB removed these data from the dataset for the purpose of developing both the VOC emissions model and the NOx emissions model, since the data deleted were identified solely on the basis of their influence on the VOC emissions model. Without some indication that these data would similarly skew the results of the NOx emissions model, their exclusion from the NOx dataset would appear to be inappropriate. Likewise, CARB removed data from two other studies as a result of discussions with stakeholders of their effect on

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[10] See Docket A-2000-10, Document Number II-D-64 ("Assessment of California Predictive Model," Work Assignment No. 2-9, Contract 68-C-98-169, SwRI Project 08.04075), December 20, 2000

[11] Where a small number of data points exert disproportionate leverage over the estimates of coefficients in a regression analysis, these observations are said to be "influential observations". In a simple bivariate regression, points that are isolated from the mass of data and are relatively distant from the means of both variables are candidates for this designation. These are points whose exclusion or inclusion alters the coefficients in the equation substantially.

the VOC equation. The intersection of statistical criteria and engineering judgements as bases for data inclusion/exclusion is frequently problematic, and we therefore hesitate to question these judgments for the VOC emissions model-building process. Nevertheless, these deletions do not seem to be well-justified for purposes of building the NOx emissions model. Taken together, these questionable or inadequately justified data exclusions contributed to our decision to do our own modeling of NOx and VOC emissions for Tech 4 vehicles.

c. Statistical approach

We examined two issues in auditing the statistical approach that CARB used: the choice of a statistical model and the statistical software used to implement that model. CARB chose a "mixed" model (with random vehicle effects and fixed fuel effects) for both its Phase 2 and Phase 3 Predictive Model development processes. These two models arrived at different results from very similar datasets and using similar statistical modeling approaches. The difference in results is partially explainable by CARB's use of different versions of the same software package. The SAS® PROC MIXED software selected for Phase 2 model development was substantially improved before the Phase 3 development process, making the necessary iterative calculations proceed to a more refined conclusion. We believe that California's selection of a mixed model was the right one (an option that was not available at the time of EPA's Complex Model development). The improvements in the software by the time of the Phase 3 model's development led to a better estimation of the "true" model. The use of this newer software resulted in an important difference in the selection of terms. The RVP-by-oxygen term that was present in the Phase 2 model no longer met the significance criteria for inclusion, leading to a model with a steeper slope relating NOx emissions to fuel oxygen content.

We also believe that CARB's choice of candidate terms to consider for possible inclusion in the final model was appropriate. The only exception to this is the question of a high-emitter term, which is discussed separately below.

d. Statistical treatment of "High-Emitters"

CARB initially considered the possibility that normal and high emitter classes might differ in their response to changes in fuel parameters. When building its NOx model, CARB concluded that there was no statistically detectable difference between the behavior of high emitters and normal emitters. EPA was surprised by that finding, since high emitters were found to behave quite differently from normal emitters in the Complex Model development process. An explanation for the difference was found in CARB's definition of "high emitters" in NOx terms rather than the hydrocarbon/carbon monoxide (HC/CO) terms used by EPA when building the Complex Model. CARB was reluctant to introduce a NOx high-emitter term into a model designed to predict NOx out of concern for the statistical complications that could result (complicated correlations between the high-emitter terms and the model's error term). While EPA understands the reasons behind CARB's approach, we believe that there are engineering reasons for carefully considering a HC/CO high emitter term when modeling NOx emissions. High HC/CO emission levels may indicate a damaged or disabled catalytic convertor and/or ineffective control of fuel/air ratios–these conditions could make the NOx emission impact from changes in fuel composition different for such vehicles than it would be for normal emitters.

e. Choice of final model

Based on the Audit, it appears that CARB's Phase 3 model-building process initially resulted in a model having too many terms, and one that did not seem to predict emissions from

certain fuels very well. As a result, CARB discarded the primary results of the Phase 3 model-building process and returned, with stakeholder support, to the terms from the earlier Phase 2 effort. The Phase 2 terms were fit to the Phase 3 database, resulting in different coefficients, and the result was adopted as the Phase 3 outcome. This abrupt change at the end of the analytic process is surprising, and does not seem to have been driven by clearly evident statistical principles. This change in analytic approach does not appear to be based on a readily understandable and supportable analytic process. The resulting uncertainty, in combination with the uncertainty related to some other of CARB's decisions (discussed above), are the main reasons for EPA's decision to pursue an independent modeling effort.

4. Effect of Oxygen on NOx Emissions from Tech 5 Vehicles

California developed models which predict the impact of fuel quality on emissions for three groups of vehicles: Tech 3, Tech 4, and Tech 5. Tech 5 represents the most recent vehicle technology and includes 1996 and later MY vehicles. The three groups were developed based on differences in their basic emission control technology. Because vehicle manufacturers are continually introducing improvements in their model lines and do so a few models at a time, there is inherently some overlap between the three groups. Still, some generalizations are possible when describing the technology typical of each group. For example, Tech 5 vehicles, compared to Tech 4 vehicles, generally have more efficient after treatment systems and meet tighter emission standards. This is due to techniques including but not limited to better air-fuel ratio control, improved oxygen storage in the catalyst, more closely coupled catalysts often involving use of palladium, and catalytic converters with two different layers of catalytic materials. These differences can cause a different response to fuel quality.

Accurately modeling the impacts of fuel quality on emissions from Tech 5 vehicles is important, as these vehicles will dominate the vehicle fleet beginning in the middle of the first decade of this century. For example, California projects that Tech 5 vehicles will emit 53% of in-use NOx emissions from light-duty vehicles and light-duty trucks in 2005.

California attempted to create an independent Predictive Model for Tech 5 vehicles based solely on emission data from these vehicles, as it did for Tech 3 and Tech 4 vehicles. However, this effort failed due to a lack of emission data reflecting the effect of a wide variety of independently varying fuel parameters. Only a few test programs have included Tech 5 vehicles. Of these programs, only the effect of sulfur on emissions was studied. Another study varied oxygen content, but with only 11 vehicles. Other fuel parameters were not varied sufficiently to discern their effect on emissions, or multiple parameters were varied at same time, preventing the discernment of the impact of individual fuel parameters.

To circumvent this problem, California grouped the emission data from both Tech 4 (1986-1993 MY) and Tech 5 vehicles and generated a Tech 5 Predictive Model from the combined set of data. The vast majority of the test data were from Tech 4 vehicles (roughly 85 percent). The Tech 5 model was allowed to have two sulfur effects, one for Tech 5 vehicles and one for Tech 4 vehicles. Otherwise, each fuel parameter was allowed to have only a single, unified effect, derived from both Tech 4 and Tech 5 vehicle emissions data. Tech 5 vehicle emissions were found to be much more sensitive to sulfur than Tech 4 vehicles. However, because the statistical model only allowed a common effect for other fuel parameters and the vast majority of data were from Tech 4 vehicles, the Tech 5 Predictive Model for non-sulfur fuel parameters is almost identical to the Tech 4 Predictive Model for these fuel parameters.

This merging of the Tech 4 and Tech 5 sets of data in developing the Tech 5 model differs markedly from CARB's approach to developing the Tech 3 and Tech 4 models. As mentioned above, only emission data from Tech 3 and Tech 4 vehicles were used to develop the Tech 3 and Tech 4 models, respectively. Thus, the impacts of fuel quality on Tech 4 vehicle emissions were not allowed to have any impact on the Tech 3 model, and vice versa. As mentioned above, CARB modeled emissions for Tech 5 vehicles differently because of the insufficiency of data with respect to non-sulfur fuel parameters. However, by grouping Tech 4 and 5 data, CARB implicitly assumed that, absent data, Tech 5 vehicles would reflect the same fuel-related emission effects as Tech 4 vehicles.

Below, we reevaluate the available data regarding the impact of oxygen content on NOx emissions from Tech 5 vehicles to assess whether this assumption is the best one that can be made in the absence of actual data from Tech 5 vehicles.

a. Studies of the Impact of Fuel Quality on Tech 5 Vehicle Emissions

There are three studies which address the impact of oxygen on NOx emissions from Tech 5 vehicles at least to some extent. The first is a study performed by the Auto-Oil Air Quality Improvement Research Program (Auto-Oil). The second study was performed by the Coordinating Research Council (CRC), a consortium of auto manufacturers and oil companies. The third study of the impact of oxygen on Tech 5 vehicle emissions was performed very recently by Toyota Corporation.[12]

[12] "Effects of Ethanol on Emissions of Gasoline LDVs," Toyota Motor Corporation, Presented to the staff of the California Air Resources Board, May 4, 2000.

b. The Auto Oil Study

The Auto-Oil study compared emissions using two fuels which met California Phase 2 RFG emission performance specifications, but one contained 2 weight percent (wt%) oxygen in the form of MTBE and the other contained no oxygen.[13] These two fuels were tested with eight Tech 4 vehicles and eleven Tech 5 vehicles (six 1994 model year, Federal Tier 1 vehicles and five more advanced prototypes indicative of post-1994 technology).

CARB cited this study in Appendix J of its decision document in support of its CaRFG3 regulation.[14] Appendix G of the decision document addresses the impact of oxygen content on CO emissions. CARB points out that the Auto-Oil study shows that an increase in oxygen content of 2 weight percent decreases CO emissions from Tech 5 vehicles by only a very small amount and that this CO decrease is not statistically significant. CO emissions from the Federal Tier 1 vehicles decreased by 1 percent, while those from the more advanced prototypes increased by 1 percent. Based solely on this information, CARB concluded that oxygen did not impact CO emissions from Tech 5 vehicles. It is interesting to note that this study indicated that the 2 weight percent oxygen did statistically significantly reduce CO emissions from Tech 4 vehicles by ten percent. Thus, two conclusions can be drawn from this CO emission data. First, Tech 5 vehicle CO emissions were not affected by oxygen content. Since CO emissions are thought primarily to be a function of the engine's ability to maintain the proper air-fuel ratio

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[13] "Technical Bulletin No. 17, Gasoline Reformulation and Vehicle Technology Effects on Exhaust Emissions," Auto-Oil Air Quality Improvement Research Program, August 1995.

[14] California Air Resources Board (CARB) Staff Report: Initial Statement of Reasons; Proposed California Phase 3 Reformulated Gasoline Regulations; released October 22, 1999 (Available in docket A-2000-10; Document II-D-6; also available at www.arb.ca.gov/regact/carfg3/carfg3.htm under "Public Hearing Notice and Related Materials".)

(notwithstanding the sulfur effects on catalytic activity), this lack of response to additional oxygen in the fuel is a strong indication that these vehicles' air-fuel ratio control systems (the combination of ported fuel injection, and feed-forward and feed-back computer control) is sufficiently accurate and fast to almost completely adjust fuel injection rates for the additional oxygen. Second, this ability of Tech 5 vehicles to adjust is dramatically better than that of Tech 4 vehicles.

Moving to NOx emissions, the same trends occur. The impact of the additional oxygen on NOx emissions from the Tech 5 vehicles is again essentially zero (1 percent decrease from the Tier 1 vehicles and no change from the advanced prototypes). This result is consistent with the finding of no impact on CO emissions. Both pollutants are sensitive to changes in air-fuel ratio in both the engine and the catalyst, though in opposite directions. Oxygen content in fuel is believed to affect emissions primarily through changes in air-fuel ratio. Again, in contrast, the additional oxygen increased NOx emissions from the Tech 4 vehicles by 4 percent. This is consistent with the 10 percent decrease in CO emissions because of the opposite response of the two pollutants to air-fuel ratio.

Thus, the Auto-Oil study indicates that Tech 5 vehicles' NOx response to oxygen differs dramatically from that of Tech 4 vehicles. It also strongly suggests that oxygen does not affect either CO or NOx emissions from Tech 5 vehicles. This conclusion is consistent with CARB's finding that oxygen content does not affect CO emissions from Tech 5 vehicles. However, it differs from CARB's implicit assumption that NOx emissions from Tech 5 vehicles will respond to oxygen content in a similar fashion as Tech 4 vehicle emissions.

c. The CRC Study

The second study, performed by the CRC, tested twelve California LEVs (two each of six different models) on five fuels which primarily differed in terms of sulfur content. However, two sets of two fuels had the same sulfur content, but differed in other non-sulfur fuel parameters. Fuels C1 and S1 both contained 30 ppm sulfur and fuels C3 and S2 both contained 150 ppm sulfur.[15] Fuels C1 and C3 were otherwise typical U.S. fuels not containing oxygen. (Their quality was very similar to that of the baseline fuel for federal RFG defined in Section 211 (k)(10)(B)(i) of the Clean Air Act.) Fuels S1 and S2 were Phase 2 California RFGs, which contained 2 weight percent oxygen. Thus, the two matched pairs of fuels based on sulfur differed in terms of nearly all the other fuel parameters. These fuels, then, are not ideally chosen if our purpose is to isolate and quantify the effects of oxygen. The usefulness of this study for our purposes stems, rather, from the fact that the vehicles being tested reflect later emission control technology than the Auto-Oil study discussed above. Also, the oxygen content did differ dramatically between the two fuels.

Because numerous fuel parameters differed in these two sets of fuels, the separate effect of each non-sulfur fuel parameter cannot be determined. The total effect of all of the non-sulfur fuel parameters, however, can be determined and compared to the predicted change in emissions from California's Tech 5 Predictive Model, which essentially reflects the impact of fuel quality on Tech 4 vehicle emissions. Table 3 summarizes the measured and predicted change in NOx emissions from the twelve vehicles.

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[15] These are nominal sulfur contents. The "matched sulfur" fuels actually differed slightly from each other in sulfur content.

Table 3: Comparison of Measured Versus Predicted Change in NOx Emissions from Phase 2: California RFG Versus Conventional Gasoline (%)

	30 ppm Sulfur Fuels (C1 vs. S1)	150 ppm Sulfur Fuels (C3 vs. S2)
Measured Change in NOx emissions (12 vehicle average)	-17.4	-13.9
Predicted Change	-0.1	+0.3

As can be seen, the emission measurements showed that the Phase 2 California RFG (including 2 weight percent oxygen) reduced NOx emissions by 14-17 percent relative to conventional (non-oxygenated) gasoline. In contrast, the Tech 5 Predictive Model predicts essentially no change in NOx emissions (0.1-0.3 percent change). Thus, some aspect of California RFG2 is causing NOx emissions to decrease more substantially, and/or is not causing as much of an increase as those predicted by the Tech 5 Predictive Model.

Table 4 shows the predicted emission change for each fuel parameter using the Beta3 version of the Tech 5 Predictive Model, calculated while holding the other fuel parameters constant.

Table 4: Predicted Change in NOx Emissions for Individual Fuel Parameters Which Varied Between Phase 2 California RFG and Conventional Gasoline in CRC Testing (%)

	30 ppm Sulfur Fuels (C1 vs. S1)	150 ppm Sulfur Fuels (C3 vs. S2)
Sulfur	-0.9	-0.9
RVP	-1.1	-1.2
T50	0.1	0.1
T90	0.7	1.0
Aromatics	-0.6	-0.9
Olefins	-0.5	-0.8
Oxygen	2.2	3.1
Total Change	-0.1	+0.3

As can be seen from Table 4, the Predictive Model projects that none of the fuel parameters will have a large impact on NOx emissions. The greatest predicted individual reduction is 1.1-1.2 percent due to lower RVP. Oxygen is projected to cause the largest increase, 2.2-3.1 percent. Assuming that the increase in NOx emissions due to oxygen content is correct, the differences in the remaining fuel parameters must be causing a 17-20 percent decrease in NOx emissions, or 14-17 percent more NOx reduction than projected by the Predictive Model. If oxygen content does not affect NOx emissions, the difference between the measured NOx impacts and the model predictions is reduced to 11-15 percent. Neither of these differences between actual and modeled emission impacts is easily explained. However, assuming that oxygen content does not affect NOx emissions, as suggested by the Auto-Oil data discussed above, reduces the error significantly and is certainly more consistent with the CRC data than CARB's implicit assumption that Tech 5 vehicles respond to oxygen like Tech 4 vehicles. The

CRC data also raises serious doubts about the ability of the Tech 5 Predictive Model to accurately project the NOx emission impacts of fuel quality differences of all sorts.

d. The Toyota Study

The third study, conducted by Toyota, consisted of testing one TLEV, six LEVs and two ULEVs on two fuels: 1) a Phase 2 California RFG with 2 weight percent oxygen in the form of MTBE and 2) a Phase 2 California RFG with roughly 3.2 weight percent oxygen in the form of ethanol. Neither fuel actually met the formal Phase 2 RFG requirements, but they were close.[16] The ethanol blend had an RVP of 7.6 psi, which is far above the allowable RVP cap of 7 psi and well above the RVP of 6.8 psi of the MTBE blend. The T50 and T90 levels of the ethanol blend were also both seven degrees Fahrenheit higher than that of the MTBE blend. It is not apparent, then, that these fuels differed only in the oxygen content and type of oxygenate used.

Toyota found that the ethanol blend increased NOx emissions for 7 of the 9 vehicles. The absolute emission data (in g/mi) were not provided, but the car-specific emissions changes averaged to a 5.5 percent increase across the cars in the study. The fuel-related differences in NOx emissions (provided as a single percent change for each test car) showed a high degree of scatter among the cars, with the greatest increase being over 20 percent and the greatest reduction being over 10 percent. Despite the predominance of NOx emissions increases with increasing

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[16] The MTBE blend actually fails the exhaust THC emission performance standard by less than 1%, assuming that this fuel was being certified against the flat limits. Against the average limits, it fails the THC performance standard by a larger margin. The ethanol blend fails NOx emission performance by 2% against the flat limits and fails both NOx and exhaust THC performance against the average limits. Toxics performance cannot be assessed as the benzene content of the fuels is unknown.

oxygen, a statistical test failed to reject the no-effect hypothesis for these data at the conventional 95 percent confidence level.[17]

EPA staff met with Toyota staff on May 4, 2000 to discuss the testing in greater detail. Toyota staff indicated that the testing was performed at various points during durability testing of certification vehicles. More details were not available at that time. Specifically, Toyota could not provide a description of vehicles tested, the mileage points of the testing, the number of repeat tests at each mileage point, the order of the testing at each mileage point, or the absolute emission levels measured at each point. There was also some question about whether the fuel tank had been completely drained between testing with the two fuels.

It is difficult to place a high confidence in this testing for a number of reasons. First, the general lack of information about the testing itself creates uncertainty as to the overall quality of the testing (e.g., repeat testing, random ordering of fuels) Second, and more importantly, the ethanol fuel not only contained more oxygen, but it had higher RVP and T50 levels. The Tech 5 Predictive Model would not project that these differences in RVP or T50 would increase NOx emissions by 5 percent. The CRC data presented above, however, indicates that NOx emissions from LEVs are highly sensitive to some fuel parameter other than sulfur and oxygen. Toyota has presented information to EPA in the past indicating that increases in T50 and T90 levels in this range can both significantly increase NOx emissions.[18] Thus, it would be very questionable to attribute even a confirmed increase in NOx emissions to just the increase in oxygen content.

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[17] Given the paucity of information about the test program, a two-tailed Wilcoxon Matched Pairs, Signed Ranks test was chosen as the most powerful test that was clearly justified.

[18] "Before the U.S. EPA, Petition to Regulate Gasoline Distillation Properties," DaimlerChrysler Corp., Ford Motor Co., General Motors Corp., and Association of international Automobile Manufacturers, January 27, 1999.

A number of automakers have completed testing LEVs with both oxygenated and non-oxygenated fuels explicitly to address the relative impact of MTBE and ethanol on emissions. No deadline has been set for releasing the results of this study. EPA at this time does not have the data, and therefore is not in a position to apply the results in assessing the impact of oxygen content on NOx emissions. Since EPA's conclusions regarding the waiver (see Section III.D) do not rely on the relationship between NOx and oxygen, however, the data from the automakers' LEV study would not change our decision.

e. Conclusions

Overall, the results of these three studies provide much stronger support for the conclusion that oxygen content likely has little or no impact on NOx emissions from Tech 5 vehicles than for the conclusion that Tech 5 and Tech 4 vehicles react similarly to oxygen content. Additional data from carefully controlled studies would be necessary to confirm this finding. However, these data will not be forthcoming for some time. The Auto-Oil data provides the strongest evidence for this conclusion. It shows that increasing oxygen content from zero to 2 percent by weight with Tech 5 vehicles did not increase NOx emissions.[19]

The CRC data support this conclusion. While NOx emissions from Tech 5 vehicles appear to be more sensitive to some fuel parameter than Tech 4 vehicles, it is highly unlikely that increased oxygen content could be causing a large increase in NOx emissions with net NOx reductions of 14-17 percent.

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[19] CARB used these same data to conclude that oxygen content did not affect CO emissions on Tech 5 vehicles, while it did affect CO in Tech 4 vehicles. Using the same criteria for NOx would lead to similar conclusions regarding the lack of effect of oxygen on Tech 5 vehicles.

Finally, too many issues surround the quality of the Toyota testing and its ability to focus solely on oxygen content to draw any meaningful conclusions from its results.

Pending new information, EPA therefore believes the best assumption to make for Tech 5 vehicles is that oxygen content does not affect either NOx or CO emissions.

5. EPA Model Building For Tech 4 Vehicles

After careful review of CARB's development of the Phase 3 NOx model as discussed in Section III.A.3, EPA has reached the following conclusions:

1. There is a substantial disparity between the NOx-oxygen relationship that emerges from the Phase 3 Predictive Model and from the other two major modeling efforts–the EPA Complex Model and the CARB Phase 2 model.
2. The three studies mentioned above have a substantial fraction of their data in common.
3. The NOx-oxygen relationship is known (from the Complex Model work) to be a relatively weak one, when compared to all of the other factors affecting NOx emissions, including such fuel factors as sulfur and olefins.
4. No single reason for the difference between previous models' characterization of the NOx-oxygen relationship and that contained in CARB's PM3 model emerged clearly from EPA's review of that model's construction.

It is difficult to identify precisely why these models reach different conclusions regarding the impact of oxygen content on NOx emissions, since the statistical techniques being used and the software to implement them have not been automated to any significant degree. The kind of "trial-and-error" exploration that might be carried out with more ordinary "general linear

models" would prove extremely time-consuming when using the statistical approach adopted by CARB and also believed by EPA to be the most appropriate now available for this kind of analysis.

Given the above considerations and questions discussed above raised by the audit of the CaRFG3 NOx model, EPA determined that it should undertake an independent modeling effort. This work investigated the direction, nature, and strength of the NOx-oxygen relationship, taking other fuel parameters into account. Because the Tech 3 vehicles' influence on the NOx emissions of future vehicle fleets is declining, and because Tech 3 modeling efforts are relatively settled, the Agency decided not to re-examine these vehicles' response to oxygen. For different reasons, Tech 5 vehicles were excluded from this effort as well. The database on Tech 5 vehicles' response to fuel parameters other than sulfur, as discussed above, is almost nonexistent and certainly not adequate to draw any strong conclusions. Thus EPA's statistical modeling effort was confined to Tech 4 vehicles (model years 1986 through 1993). EPA's statistical consultant's report of this analysis may be seen in the docket for this rulemaking (See Docket A-2000-10, Document Number II-D-65:"Building the NOx Model," Work Assignment No. 2-9, Contract 68-C-98-169, SwRI Project 08.04075; December 20, 2000). Some assumptions underlying this analysis are presented below, along with the results of the work.

a. Tech 4 modeling decisions and assumptions

The overall body of data analyzed by CARB for its Phase 3 model had not been significantly expanded at the time of EPA's analysis. Since this analysis was performed for the purpose of drawing conclusions about California emissions, EPA followed CARB's convention of confining the analysis to California-certified vehicles. To EPA's knowledge, the overall

database used by CARB is the only major body of data available for answering questions about fuel effects on California vehicle emissions. The dataset was further restricted to eliminate tests performed on fuels with extreme parameter values. While it was desirable to begin the analysis with a generally wide range of parameter values to permit sensitive detection of effects, some fuels in the body of studies making up the database were judged to be outside of the range of usable fuels. These limitations, listed below along with other deletions made for practical or statistical reasons, are very similar to those imposed by CARB:

1. An observation was deleted if any of its fuel properties were in any of the following categories: RVP>10, Sulfur>1000, Oxygen>4, T50>250, or T90>374.
2. All observations from Fuel "Y" in the ARBATLOX study were deleted because CARB indicated this fuel generated spurious test results.
3. Extreme temperature data were eliminated from the data base when the drybulb temperature value for an emissions test was less than 68 or greater than 95. In these situations, the entire observation was deleted from the data base. Such test conditions violate the testing protocol and cannot be expected to yield reliable results.
4. If an observation was missing any of the seven fuel properties under investigation, the entire observation was deleted. Thus, if a value for RVP, Aromatics, Olefins, Sulfur, Oxygen, T50 or T90 was missing, the observation was deleted. This was necessary since NOx emissions were to be modeled as a function of all of the fuel characteristics taken together.

5. For the GMCONFRM study, the ETBE, ETOH and TAME values were set to zero since they were previously missing.

After some discussion and preliminary analysis, EPA decided to use T50 and T90 to represent the distillation properties of the test fuels, despite some theoretical reasons for preferring E200 and E300.[20] Information adequate to determine the E200/E300 values was not present for all of the fuels in the data, and corrections attempted without full information might introduce error of unknown magnitude and direction.

Where CARB elected not to model high-emitters separately, EPA decided to explicitly identify them and model their behavior in its analysis. In the Complex Model the high emitters actually had a NOx slope with oxygen that was different in direction from that of the normal emitters. The ability to predict high emitter effects separately was more important in constructing the Complex Model than for subsequent modeling efforts, since such vehicles were substantially under-represented in the data. But the effect was deemed potentially important enough to examine in this analysis, especially since the categorical variable representing the

[20] Changes in E200 and E300 refer to changes in the volume percentage of fuel which distill at or below 200 deg F and 300 deg F, respectively. As such, changes in E200 and E300 are directly related to the change in the fractions of fuel which evaporate in the engine's intake system and the combustion chamber prior to the initiation of combustion. A 5 volume percent increase in E200 implies that 5 percent more of the fuel is likely to evaporate prior to combustion. Since emissions are a strong function of unburned fuel, E200 and E300 are theoretically related to the emission forming process. Also, the units of E200 and E300 (being volume percent) are analogous to those for aromatic and olefin content (which are also in the form of volume percentages) and thus, form a more consistent set of modeling parameters. Finally, the weakness of distillation temperatures (T50 and T90) are that they hold the percentage of fuel evaporated constant (at 50 percent and 90 percent, respectively) and vary the temperature needed to obtain these evaporation percentages. This is not analogous to the thermodynamic processes existing in the engine's intake system or combustion chamber. For example, when a fuel gets heavier (T50 and T90 increase), less fuel evaporates in the engine, as opposed to more heat getting sent somehow to the engine to evaporate the same amount of fuel. E200 and E300 more naturally reflect the response of the engine to lighter or heavier fuels.

high-emitters was determined as a function of hydrocarbon and carbon monoxide emissions rather than the NOx emissions measure used by CARB.[21]

EPA's consultant subjected the NOx emissions dependent variable to a log transformation to correct the strong positive skew in its distribution and to make it possible for the data to meet basic requirements for use of the regression techniques that had been chosen to analyze the data[22]. After data deletions, the fuel properties' values were standardized so that each had a mean of zero and a standard deviation of one. This was done to hold down the size of the coefficients. Table 5 lists the information needed to destandardize the coefficients of the models that result from the analysis.

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[21] Also called a "dummy", such a variable is actually a set of binary-coded variables numbering one fewer than the number of categories to be represented. In this case, since each vehicle is either a high emitter or not (two categories), there need be only one variable placed in the data set and coded "0" for normal emitters and "1" for high emitters. The problem of correlations between the high emitter term (and any interaction terms that involve it) and the error term, discussed earlier, is minimized in EPA's analysis by the fact that the high emitter term is not constructed from the same parameter as the dependent variable in the analysis, NOx emissions. In this analysis, a vehicle was coded as a high emitter if its average total hydrocarbon (THC) emissions exceeded 0.82 gram per mile and/or its average carbon monoxide (CO) emissions exceeded 6.8 grams per mile.

[22] Use of regression requires the assumption that the variance of the dependent variable not differ substantially for different fixed regions of the independent variable(s). This assumption, termed "homoscedasticity", cannot easily be met by a dependent variable that is strongly skewed without a corrective transformation.

Table 5. Means and Standard Deviations of Fuel Properties

Fuel Term	Mean	Standard Deviation	Sample Size
RVP	8.445335	0.780184	7031
T50	206.815503	17.906267	7031
T90	312.126198	22.099331	7031
AROM	28.082805	7.383169	7031
OLEF	6.974371	4.932872	7031
OXYGEN	1.347629	1.251882	7031
SULFUR	182.060319	140.783197	7031

b. Statistical methods

EPA decided that the most appropriate statistical model to use for this purpose was one that treated the very large variability in NOx emissions among vehicles as a random variable, but that treated the fuel effects as fixed. We discussed the advantages of such an approach above in connection with CARB's modeling effort which used the same approach, and they are treated at greater length in the previously cited "Building the NOx Model" (See Docket A-2000-10, Document Number II-D-65).

Candidate terms initially made available for possible use in the model included, in addition to the seven linear properties, the squares of the same seven properties (allowing for non-linear effects), 21 interactive terms (products of two linear terms), a high-emitter term, and the seven interactions of the high-emitter term with the fuel properties.

The seven linear fuel properties were forced into the model without regard to their p-values[23] in order to ensure that the linear form of any variable that was subsequently involved in

[23] For the purpose of this discussion, the p-value may be understood as the likelihood that a decision to include the term in question in the equation will prove to be a bad decision in the sense that the term actually fails to explain any variance in the dependent variable–NOx emissions in this case. So a p-value of, say, 0.02 can be taken to mean that there are 2 chances in 100 that a decision to include the term in question will not really improve the amount of NOx variance explained, given the other terms that are already in the model. The p-value is a function of a number of factors

higher-order or interactive terms would be present. Beyond this stage, terms were introduced one by one in what is termed a "stepwise" manner in order of their statistical significance (the term with the smallest p-value is introduced first, and so on). At each step the significance level of each of the terms already in the model was examined, and any terms (other than the seven linear ones) whose p-value rose above 0.05 were taken out, but remained candidates for possible later re-inclusion[24].

When no candidate terms with p-values less than 0.05 remained to be considered for inclusion, the initial model construction process was complete. The next steps involved evaluation of the resulting models. Measures of information content[25] were used to evaluate the models created at each step after the linear terms, identifying the point at which additional terms cause an "overfit" condition, where additional terms fail to explain enough additional variance to justify their inclusion and may actually detract from the model's ability to predict results outside of the sample data. The measures of model information content that were employed in evaluating these models are designed to assess a model's overall ability to predict the dependent variable--

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involved in the analysis and is a quantitative indicator of what is called "statistical significance". The 5% level, more frequently referred to as the 0.05 level, is a cut point for the p-value, established by common convention for concluding that a term has little to offer in the way of explanatory power. A term with p>0.05 is considered to be a poor term to use in building a model.

[24] Terms may move in and out of the model in this way because of the way they are correlated with other terms being considered.

[25] Akaike's Information Criterion (AIC): This is a comparative measure of the information content in a model. It is particularly useful in deciding whether additional terms should be added to the model or terms already added should be retained. It, like the BIC below, has no maximum value and, thus can't be used to say how good a particular model is in an absolute sense. Schwarz's Bayesian Criterion (BIC): Outwardly similar to the AIC above, this criterion is sensitive to slightly different aspects of model behavior. It has the same limitations that the AIC does.

NOx emissions, in this case as a function of all of the predictor variables included. The AIC and BIC numbers are excellent screening tools to isolate a set of models that do a good job of explaining the variance in NOx, but they do not really help to determine which of the otherwise best fitting models best describe the relationship between NOx emissions and fuel oxygen content[26].

In addition to the models that were generated directly by the stepwise process, several other models were examined. Most of these came from situations where a set of terms that were candidates for inclusion at a particular step had similar p-values. Certain of these rejected terms were added to the model and their AIC and BIC values computed to see if they were competitive with the models that emerged from the stepwise process described above. We also considered two models developed using the "random balance" method developed by H. T. McAdams and used by CARB in the development of their predictive model and in the construction of the EPA Complex Model. This technique, explained at greater length in the previously cited SwRI report on building the NOx model, simplifies an already-developed model by eliminating terms that contribute minimally to explaining variance in the dependent variable within a restricted range of the various fuel properties. The "Step-3" model was put through this process, and the result was to eliminate the RVP and oxygen-by-sulfur terms. When the "step 5" model was analyzed similarly, the squared sulfur term and, again, the oxygen-by-sulfur term were eliminated. While the simplified version of the "Step-5" model (now called RB-3) was carried forward into

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[26] For example, a model that explained a large fraction of the NOx emissions variance (using values of sulfur, olefins, etc.) might badly mis-characterize the NOx oxygen relationship (all things being equal) because of gaps in the distribution of oxygen content across the fuels in the dataset. Despite its poor and counter-intuitive handling of the NOx/oxygen relationship, such a model might have very high AIC and BIC values because of its overall explanatory power.

subsequent consideration, EPA ultimately elected not to use the random balance-generated models. The simplification achieved by random balance, though useful when developing a model for regulatory/compliance purposes (where model simplicity is extremely important to those who must use the model to formulate gasoline), was not needed in the context of evaluating this waiver request (where the most important objective is to characterize the relationship between NOx emissions and oxygen content as precisely as possible). All of the models that were developed from the stepwise process and other approaches (as described above) are listed in Tables 6 and 7 below, along with the CARB PM3 model (see the column titled "CARB" in Table 7) after refitting to EPA's dataset (for comparison purposes)..

Table 6. Estimated Coefficients for First Half of Final Models Fit to Log(NOx)

(Bold italics indicate non-significant terms at 0.05 significance level)

Standardized Term	Step-1	Step-2	3	Step-3	5	6	7
Intercept	-0.6606	-0.6603	-0.6606	-0.6656	-0.6651	-0.6624	-0.6737
RVP	0.01257	0.009093	0.01172	0.009694	0.007673	0.008390	***0.006188***
T50	***0.000129***	***-0.00245***	***0.000084***	***0.001804***	***0.001173***	***0.000312***	***-0.00475***
T90	***0.006597***	***0.00719***	0.007879	***0.005543***	***0.006239***	***0.006213***	***0.007587***
AROM	0.01498	0.01587	0.01431	0.01524	0.01407	0.01501	0.01209
OLEF	0.01978	0.01988	0.01949	0.01940	0.01966	0.01990	0.01969
OXYGEN	0.01795	0.01240	0.01728	0.01333	0.01371	0.01351	0.008245
SULFUR	0.04449	0.04171	0.04387	0.04201	0.04201	0.04195	0.04205
HI-EMIT	0.3963	0.3960	0.3963	0.3965	0.3960	0.3961	0.3969
OXY*SUL		-0.01506		-0.01647	-0.01627	-0.01402	-0.01325
T50*T50				0.006974			
OXY*OXY							0.01120
OXY*T50					-0.00830		
OXY*T90			-0.00510				
OXY*ARO						-0.00547	

Table 7. Estimated Coefficients for Second Half of Final Models Fit to Log(NOx)

(Bold italics indicate non-significant terms at 0.05 significance level)

Standardized Term	RB-3	Step-4	10	CARB	Step-5
Intercept	-0.6829	-0.6791	-0.6550	-0.6159	-0.6690
RVP	0.009120	***0.006838***	***0.005755***	*0.006922*	*0.00487*
T50	***0.000275***	***-0.00062***	***0.001255***	***-0.00036***	***-0.00061***
T90	***0.005640***	***0.006002***	***0.005456***	***0.005731***	***0.005237***
AROM	0.009442	0.01139	0.01395	0.009896	0.01126
OLEF	0.01915	0.01924	0.02039	0.01944	0.02003
OXYGEN	0.01245	0.009105	0.01385	0.01324	0.009231
SULFUR	0.04520	0.04232	0.04677	0.04518	0.04710
HI-EMIT	0.3982	0.3974	0.3947		0.3961
OXY*SUL		-0.01464	-0.01598		-0.01434
T50*T50	0.005102	0.006929			0.006771
OXY*OXY	0.01521	0.01128		0.01226	0.01132
SUL*SUL			-0.00606		-0.00615
OXY*T50			-0.00804		
OXY*ARO				-0.00633	
SUL*T90				0.005984	

A group of models emerging from the above processes were carried forward as candidates and subjected to further examination. This group of models is listed in Table 8 below, along with measures of the models' "goodness of fit" to the data.

Table 8. List of Candidate Models for NOx Emissions

Model	No. of Terms	AIC	BIC	RMSE	Vehicle Error	Fuel Terms (In Addition to Linear Terms)
Step-1	8	2657.0	2633.1	0.1138	0.5809	HI
Step-2	9	2673.1	2646.8	0.1133	0.5825	HI, OXY*SUL
3	9	2670.1	2643.8	0.1129	0.5813	HI, OXY*T90
Step-3	10	2681.9	2653.2	0.1126	0.5827	HI, OXY*SUL, T50*T50
5	10	2678.7	2650.0	0.1128	0.5827	HI, OXY*SUL, OXY*T50
6	10	2675.6	2646.9	0.1129	0.5825	HI, OXY*SUL, OXY*ARO
7	10	2672.6	2646.3	0.1132	0.5823	HI, OXY*SUL, OXY*OXY
RB-3	10	2665.7	2639.4	0.1130	0.5808	HI, OXY*OXY, T50*T50
CARB	10	2622.9	2596.6	0.1134	0.6433	**OXY*ARO, OXY*OXY, SUL*T90**
Step-4	11	2681.5	2652.8	0.1125	0.5824	**Step-3 Terms, OXY*OXY**
10	11	2677.5	2648.8	0.1128	0.5834	**HI, OXY*SUL, OXY*T50, SUL*SUL**
Step-5	12	2680.4	2651.7	0.1125	0.5833	**Step-4 Terms, SUL*SUL**

A number of checks on the most promising models were performed at this stage of the analysis process including residual analysis and additional exploration of high-emitter effects. These checks, which are discussed in more detail in the SwRI report on building the NOx model, did not identify any problems with the set of models or any significant amount of "outlier" data. The high-emitter term and its interaction terms contributed significantly to explaining NOx variability, but the HC/CO high emitter data differed from the normal emitter data mostly with regard to their overall level of NOx emissions (high HC/CO emitters also tended to have high NOx emissions). The NOx emissions of these vehicles did not seem to respond differently from the emissions of normal emitters to changes in fuel oxygen.

c. Variability in model predictions

Considering that oxygen was only one of several predictor variables involved in modeling NOx emissions, it is not surprising that a set of alternative NOx emissions models would have quite different predictions of the NOx emissions effect obtained by changing the oxygen concentration in the fuel. Table 9 shows the variability among the various models in predicted NOx emissions change as a function of changing the oxygen concentration from zero to 2 percent by weight.

Table 9: NOx Emissions change resulting from adding 2 weight percent oxygen to fuel that initially contained no oxygen (holding other parameters at California flat limits)

Model	NOx % change @ 2% oxy
Step-3	5.29
6	5.23
Step-2	4.87
5	4.84
10	4.82
Step-4	3.20
Step-5	3.16
3	3.07
1	2.91
7	2.80
CARB	1.42
RB-3	0.64

Other than the CARB Phase 3 model and the random balance model developed from the Step-3 model, the models' predictions fall into two clusters, with NOx changes of approximately 5 percent and 3 percent, respectively. These "clusters" do not necessarily remain together in the face of changing other fuel properties, but they do provide a useful summary of the modeling results.

d. Model selection

Given the fairly large amount of predictive error that can be expected from a single model when predicting NOx emissions as a function of oxygen content and the substantial variability among the models themselves regarding that relationship, selecting the most appropriate model or set of models to carry forward in this overall analysis was not entirely straightforward. As mentioned previously, selection of the single model with the highest values of the AIC and BIC criteria could not be easily justified. Averaging the effects (on NOx emissions) of varied oxygen and other fuel components of all of the models shown in Table 9 above is also problematic, since

it gives all of the models equal weight, including some models with comparative disadvantages relative to the others (significantly lower AIC and/or BIC measures).

Based upon substantially lower information content (AIC and BIC values), we decided upon removal of the CARB model, the Step-1, and the RB-3 models (in the case of the RB-3 model, there are additional reasons for removal that have already been discussed). Other models were dropped from consideration on the grounds that they explained insufficient additional NOx variability relative to earlier models (with fewer terms) and thus represented a condition of "overfit". Eliminated in this fashion were the Step-5, 10, and Step-4 models. Six models remained after these exclusions were made. The Step-2 and Step-3 models and models 5 and 6 predict the NOx emissions effect of adding 2 percent oxygen by weight at approximately a 5 percent increase; models 3 and 7 predict values closer to a 3 percent increase. These effects are all calculated with other parameters at the California flat limits, a situation unlikely to occur under real-world conditions where the non-oxygenated gasoline would be formulated differently from the oxygenated gasoline.

Left with six models that are all almost indistinguishably good predictors of NOx emissions generally, but that yield somewhat divergent predictions of the effect of oxygen on NOx, EPA is disinclined to select a single model. We prefer to determine this effect as an average of the predictions from the six remaining models. Such an approach might not be the best option for a regulatory agency developing a tool to certify gasoline, due to the added complexity it would impose on refiners trying to make compliant gasoline. In the uses to which the NOx models are to be put in this waiver evaluation, oxygen varies more than other NOx-related properties. Oxygen is a critically important variable in this analysis, one that these

candidate models do not all handle identically. Moreover, the uneven distribution of oxygen content among the fuels in the database contributes to our uncertainty that any one of these models was clearly preferable. EPA believes that averaging the NOx predictions of this group of models is justified.

6. Summary of findings

In summary, our examination of the Phase 3 predictive model, and our effort to develop alternative Tech 4 NOx models indicate that for Tech 4 vehicles NOx emissions do increase as oxygen increases when the effects of other properties are held constant. Our review of CARB's description of the Tech 3 model development process, the observation that little data were added to the PM2 database for these vehicles, and that there was little change from the Phase 2 model in the resultant NOx equation all suggest that this model may properly characterize the direction of the NOx/oxygen relationship for these vehicles. Our modeling effort supports the conclusion that NOx increases with oxygen for Tech 4 vehicles. Our alternative models predict a somewhat larger increase in NOx emissions with oxygen addition than CARB's Tech 4 model, but the level of uncertainty regarding this relationship makes difficult to quantify precisely this relationship with high confidence.

The small amount of Tech 5 data used to develop the Tech 5 portion of the predictive model leaves considerable uncertainty about the NOx/oxygen relationship for this group. For reasons discussed in greater detail earlier, EPA believes the most reasonable assumption is that fuel oxygen content changes would have no effect on the NOx emissions of Tech 5 vehicles.

While we find that NOx emissions are likely to decrease as fuel oxygen decreases, either as quantified by the predictive model or by some alternative model, such finding is not enough,

by itself, to decide whether to grant California's waiver request. The effect on NOx of reduced oxygen use in California fuels cannot be determined solely by investigating the validity of the Phase 3 predictive model. We must also consider the properties of actual non-oxygenated and oxygenated fuels that would be used in California if a waiver were granted, as well as the likely penetration levels of non-oxygenated fuels. Quantification of expected NOx reductions is explored in Section III.B below.

B. Effects on NOx of reduced oxygen use in California

1. Actual fuels that would be used in California if a waiver were granted

In order to determine the likely impact of a waiver on NOx emissions performance, it is necessary to consider the changes in all fuel properties that would occur as a result of oxygen removal and the net effect of these property changes on NOx emissions. Each refiner would make refinery-specific decisions about how to most profitably blend CaRFG3 in the absence of an oxygen mandate. A refiner may elect to produce oxygenated CaRFG3, non-oxygenated CaRFG3, or both. Each refiner's blending decisions may impact the way other refiners produce both oxygenated or non-oxygenated CaRFG3, since they may purchase ethanol and other blendstocks whose price is affected by supply and demand. In addition to these economic considerations, refiners must meet the predictive model's emission equivalency requirements for hydrocarbons (or ozone formation), and toxics. Refiners must also compensate for the volume and octane loss associated with oxygenate removal. Replacement of the oxygenate with other refinery streams will result in changes to other properties which are parameters of the predictive model and alternative models.

A refiner electing to produce California RFG without oxygen could legally use a recipe with exactly the same NOx emissions performance as the two percent flat limit reference fuel, as long as the other predictive model performance constraints were met. In such a recipe, changes in other predictive model parameters which increase NOx emissions, (e.g. olefins) would have exactly negated any estimated NOx benefit due to oxygen removal. If that were to occur, removing oxygen would not change the overall NOx emission levels for that fuel.

Refiners will attempt to produce zero oxygen California RFG in an economically optimal manner subject to the above constraints. Their optimum recipes, however, may or may not overcomply for NOx, or may just meet the NOx performance standard. We would not expect a net NOx benefit from oxygen removal and other property changes unless NOx emissions decrease with decreasing fuel oxygen content, independent of other properties. Determining that this directional relationship exists when other properties are held constant requires consideration of the predictive model along with any alternative models which we developed. Determining that this relationship exists when other properties are allowed to vary requires not only selection of the model or models which may reasonably represent the relationship between NOx emissions and fuel properties, but consideration of what these other fuel property values would be if oxygen were no longer required.

CARB attempted to demonstrate, through the use of a simulation, described in Sections I.D. and II, that the net effect of oxygen removal would be a reduction in NOx emissions. This simulation constructed possible combinations of fuel properties for zero oxygen gasoline and two percent oxygen gasoline. The simulation identified those combinations which would be certifiable using California's Phase 3 predictive model with the recently adopted Phase 3 flat

limits as reference specifications. California reported that the average reduction, relative to the reference specifications, for the certifiable zero oxygen recipes was 1.7 percent greater than the average reduction for the two percent recipes.[27]

The simulation demonstrated that various hypothetical zero oxygen recipes will satisfy the predictive model emissions equivalency constraints for NOx, HC and toxics; i.e. are allowable under the CaRFG3 regulations. The simulation also demonstrated that a number of allowable hypothetical zero oxygen recipes have better NOx emissions performance than a number of allowable hypothetical two percent oxygen recipes. The simulation did not find that all identified allowable zero oxygen recipes have better NOx emission performance than all identified allowable two percent oxygen recipes. It found, rather, that the average NOx performance of these zero oxygen recipes was better than the average NOx performance of these two percent oxygen recipes.

Had the simulation found superior NOx performance in all zero oxygen recipes, it would have arguably confirmed that the net effect of oxygen removal would be a decrease in Phase 3 predictive model-estimated NOx emissions, regardless of other fuel property changes. Use of the difference in average performance between zero oxygen and two percent oxygen recipes to estimate the net effect of oxygen removal is problematic, however. To argue that the simulation methodology employed– use of averages as measures of NOx performance–reflects what would occur if a waiver were granted, implicitly assumes that each allowable zero oxygen or two percent oxygen recipe would represent an equal volume of gasoline in its respective gasoline

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[27] The December 24, 1999 letter from Michael P. Kenney to Robert Perciasepe reported the simulation-based difference as 1.5% The February 7, 2000 letter revised this estimate to 1.7%.

pool. We do not agree with this assumption. Many of these hypothetical recipes are likely to be technically and/or economically infeasible and represent little or no CaRFG3 production, while others are likely to represent substantial amounts of production. Since the emissions performance of each allowable zero oxygen or two percent oxygen recipe was given the same weight when calculating the average NOx performance of its group, this average may not represent true average performance. Thus, CARB's simulation shows that the predictive model leaves room for better NOx performance in zero oxygen CaRFG3 than in two percent oxygen CARFG3, but does not force better NOx performance. Furthermore, even if the simulation accurately predicted average performance for the zero oxygen and two percent oxygen pools, granting the waiver would not guarantee that the full 1.7 percent NOx performance advantage would be realized. The actual difference would depend on the extent to which oxygenated and non-oxygenated CaRFG3 were produced.

In a waiver scenario, it is likely that a mix of oxygenated and non-oxygenated CaRFG3 would be produced, but a performance benefit may or may not apply to the non-oxygenated portion of the market relative to the oxygenated portion. Any such benefit would depend on the fuel properties associated with both the non-oxygenated portion of the gasoline pool and the oxygenated portion of the pool.

2. Penetration levels of non-oxygenated fuels in California

We do not believe that elimination of the oxygen mandate would eliminate the use of oxygen in California reformulated gasoline. In fact, we expect that refiners would use a significant amount of ethanol to help compensate for gasoline volume and octane loss resulting from California's MTBE ban. Refinery modeling, conducted by MathPro, Inc., supports this

conclusion. MathPro, under separate contracts to Chevron/Tosco[28] and to the California Energy Commission (CEC)[29], used its refinery linear programming model to investigate the likely effects of an MTBE ban and the elimination of the oxygen mandate on gasoline reformulation in California. We examined these MathPro modeling studies to help define how CaRFG3 would be made and the likely penetration levels of non-oxygenated CaRFG3 in a waiver scenario. These studies, however, were completed before the Phase 3 predictive model was finalized, contained questionable assumptions, and did not consider certain other factors likely to influence the extent of oxygen use in California RFG in the absence of an oxygen mandate. Section III.B.2.a. below provides a description of these studies as background to the most recent analysis conducted.

a. Previous analyses

The Chevron-Tosco analysis looked at various combinations of ethanol price assumption, predictive model mode (i.e. flat limit or averaged limit compliance), and time period ("intermediate" 3 year and "long term" 5 year). The Chevron-Tosco report concluded that the optimal "cost minimizing" share of non-oxygenated CARB gasoline ranges from about 20 percent to 40 percent, depending on time period and predictive model mode. This analysis assumed the Phase 2 predictive model requirements, and that oxygenated RFG would contain 2.7 percent oxygen in a split market.

MathPro analysis for the CEC included modeling of various split market cases, with fuel requirements determined by versions of the Phase 3 predictive model. This modeling also

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[28] " Potential Economic Benefits of the Feinstein-Bilbray Bill", MathPro Inc., March 18, 1999. Included as Appendix O in the CARB staff report "Proposed California Phase 3 Reformulated Gasoline Regulations" October 22, 1999.

[29] "Analysis of California Phase 3 RFG Standards", MathPro Inc., December 7, 1999.

assumed a 2.7 percent oxygen content in RFG. The split market cases modeled a CaRFG pool consisting of 39.1 percent non-oxygenated and 60.9 percent oxygenated gasoline. The report also analyzed cost savings for various fractions of non-oxygenated gasoline relative to a 100 percent oxygenated (at 2.7 percent) case. These cases showed that the cost savings increased rather sharply between 29.4 percent and 39.1 percent non-oxygenated gasoline and remained fairly flat at greater non-oxygenated proportions, up to 58.7 percent, the maximum non-oxygenated fraction shown.[30]

In summary, neither modeling analysis precisely captured the set of conditions that will apply with a finalized predictive model and CaRFG3 standards. However, this modeling did indicate that, under a broad range of conditions, it is likely that the California RFG pool, in the absence of an oxygen mandate, would contain substantial amounts of both oxygenated and non-oxygenated gasoline. We believed that this modeling, while not ideal, provided the best estimate available at the time of our initial analysis of the non-oxygenated market share that would occur if a waiver were granted. Based on these studies, we reasonably anticipated that 40 percent of CaRFG3 would be produced without oxygen. While the Chevron/Tosco modeling suggested that 40 percent non-oxygenated penetration might be on the high end of the likely range, the CEC modeling showed maximum cost savings above the 39.1 percent point. Since this CEC modeling more closely modeled the requirements applicable to CaRFG3, we placed more emphasis on these results, and also used this study to derive fuel property estimates for our

[30] See Exhibit 7 in MathPro (December 7, 1999). Cost savings are shown for non-oxygenated gasoline volumes at increments of 100 kbbl/day for the refinery modeled. The 300 kbbl/day volume represents 29.4 percent of the pool and 400 kbbl/day is 39.1 percent.

analysis.[31] Since both studies showed that a 40 percent non-oxygenated market share could be optimum in various scenarios, and since the CEC study pointed to this market share, we believed that a 40 percent assumption was warranted. However, we recognized that there was uncertainty about the likely oxygen content of oxygenated CaRFG3 in a split market. This oxygen content assumption could affect the estimate of the optimum non-oxygenated market share in a split market, as well as the estimates of likely fuel properties. Thus, we elected to conduct additional refinery modeling which estimated the likely non-oxygenated market share under a variety of scenarios which included use of oxygen at both 2.0 weight percent and 2.7 weight percent in a split market.[32]

b. Results of most recent analysis

We contracted with MathPro to conduct additional refinery modeling to further resolve questions about fuel properties, oxygenated/non-oxygenated market shares and oxygen content. (The results of MathPro's analysis are contained in its report titled "Analysis of the Production of California Phase 3 Reformulated Gasoline With and Without an Oxygen Waiver", which is available in Docket A-2000-10, Document Number II-D-66.) Both fuel property and oxygenated/non-oxygenated market share estimates for the cases modeled are shown in Table 10.

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[31] However, the MathPro CEC study did not incorporate the finalized CaRFG3 predictive model reference specifications.

[32] EPA's rationale for conducting additional refinery modeling and utilizing the results to estimate the likely emissions impacts of the oxygen waiver is discussed more fully in Section IV.C.2 .

Table 10: Summary of refinery modeling results

Exhibit 1: Summary of Refinery Modeling Results -- Gasoline Pool Splits and Gasoline Properties

	Model Formulation											
	No Unocal Patent, Pool Flat Limits, Fixed Property Deltas						Unocal Patent Avoided, Grade by Grade Flat Limits, Variable Property Deltas					
	National MTBE Use Continues*			National MTBE Use Reduced**			National MTBE Use Continues*			National MTBE Use Reduced**		
	No Waiver	Waiver		No Waiver	Waiver		No Waiver	Waiver		No Waiver	Waiver	
	All Oxy	Oxy	NoOxy	All Oxy	Oxy	NoOxy	All Oxy	Oxy	NoOxy	All Oxy	Oxy	NoOxy
ETHANOL @ 2.0 wt%												
Share of Gas Pool	100%	50%	50%	100%	35%	65%	100%	50%	50%	100%	26%	74%
Properties												
RVP	6.66	6.60	6.60	6.66	6.60	6.60	6.74	6.62	6.60	6.74	6.60	6.60
Oxygen	2.0	2.0	0.0	2.0	2.0	0.0	2.0	2.0	0.0	2.0	2.0	0.0
Aromatics	24.1	26.5	23.0	24.1	19.1	28.6	23.3	24.3	26.9	23.3	28.6	24.3
Benzene	0.64	0.62	0.57	0.64	0.77	0.51	0.57	0.60	0.46	0.57	0.51	0.49
Olefins	4.4	3.4	5.9	4.4	4.6	4.7	3.9	3.7	2.4	3.9	2.9	3.9
Sulfur	15	17	8	15	17	7	10	13	8	10	12	10
E200	47.2	46.8	47.7	47.2	45.2	48.7	46.4	46.2	48.1	46.4	46.1	47.7
E300	87.6	88.3	87.4	87.6	90.6	87.6	88.7	87.7	87.2	88.7	88.2	88.0
T50	208	208	206	208	213	203	210	210	205	210	210	206
T90	307	305	307	307	298	307	304	307	308	304	305	306
ETHANOL @ 2.7 wt%												
Share of Gas Pool	100%	60%	40%	100%	40%	60%	100%	65%	35%	100%	46%	54%
Properties												
RVP	6.85	6.76	6.60	6.85	6.60	6.60	6.84	6.73	6.60	6.84	6.69	6.60
Oxygen	2.7	2.7	0.0	2.7	2.7	0.0	2.7	2.7	0.0	2.7	2.7	0.0
Aromatics	23.2	25.7	24.8	23.2	22.4	28.6	23.3	26.3	21.2	23.3	25.3	25.7
Benzene	0.70	0.66	0.52	0.70	0.71	0.53	0.68	0.63	0.52	0.68	0.65	0.49
Olefins	3.8	2.8	6.0	3.8	2.8	4.1	3.8	1.9	6.3	3.8	2.8	3.9
Sulfur	10	10	12	10	12	10	9	8	12	9	10	9
E200	46.9	46.2	49.0	46.9	44.9	49.2	46.6	45.4	47.6	46.6	45.4	47.9
E300	88.1	88.6	85.8	88.1	87.7	87.4	88.0	89.0	86.8	88.0	88.3	87.6
T50	208	210	203	208	214	202	209	212	206	209	212	206
T90	305	304	312	305	307	307	306	303	309	306	305	307

* Delivered ethanol price of $40 to $45 per barrel.
** Delivered ethanol price of $50 to $55 per barrel.

Source: Table 10 excerpted from MathPro, 2000; "Analysis of the Production of California Phase 3 Reformulated Gasoline With and Without an Oxygen Waiver"; December, 2000; available in Docket A-2000-10, Document Number II-D-66.

Table 10 shows non-oxygenated CaRFG3 shares ranging from 35 percent to 74 percent, with six of the eight cases being greater than the 40 percent non-oxygenated share we had assumed based on earlier modeling. The analysis predicts, all else being constant, a decrease in non-oxygenated market share with an increase in oxygen content from 2.0 percent to 2.7 percent by weight. (This is found by comparing each 2.0 percent waiver case with its corresponding 2.7 percent case.) Also, it predicts that a reduction of MTBE use outside of California would result in an increase in the non-oxygenated market share of the CaRFG3 pool. (This is found by comparing each of the cases which differed only by national MTBE use. This relationship is expected since reduced use of MTBE outside of California would result in higher ethanol prices for California refiners.) The Unocal Patent may also affect the non-oxygenated/oxygenated market split. [33] (According to MathPro, avoidance of T50 less than 210 º F could limit the use of alkylate for premium CaRFG3, possibly increasing the use of oxygen.) MathPro has also concluded that the economic advantage of using 2.7 percent oxygen versus 2.0 percent oxygen in a split oxygenated/non-oxygenated waiver market is "too close to call". Consequently, we cannot rule out either oxygen content as unlikely, and restrict the range of market share estimates on this basis. (The lowest non-oxygenated market share, 35 percent, occurs in a 2.7 percent case, the highest, 74 percent, in a 2.0 percent case). Thus, we can conclude that under a number of sets of foreseeable "waiver" circumstances, there will be substantial quantities of both oxygenated and non-oxygenated CaRFG3 produced. The previous estimate of 40 percent non-

[33] The Unocal patent described reformulated gasoline in terms of broad ranges of properties such as RVP, T50, T90, olefins, paraffins, and octane. The first four of these properties are specifically covered by the California RFG regulations.

oxygenated CaRFG3 falls within the range of estimates in the EPA MathPro modeling. This modeling shows that the share could vary substantially, however, depending on the set of conditions that exist. Clearly, the approach we took in our earlier analysis, which selected a fixed 40 percent non-oxygenated CaRFG3 market share (and only a single set of oxygenated and non-oxygenated CaRFG3 properties), did not provide a robust basis for the evaluation of the potential emission impacts of this waiver. The EPA MathPro modeling provides a number of alternative cases, incorporating the finalized version of the Phase 3 predictive model and CaRFG3 flat limit reference specifications. This allows us to examine potential waiver emissions impacts under various alternative scenarios and determine if the waiver is warranted under a variety of potential conditions.

3. NOx reduction due to reduced oxygen use taking into account actual fuel use.

We concluded that forecasts of CaRFG3 properties with and without an oxygen waiver were necessary to rigorously evaluate the merits of the waiver request. As noted in the preceding section, our initial analysis of potential emission effects used property information extracted from MathPro's December 7, 1999 report to CEC. We realized, however, that additional refinery modeling could potentially provide more accurate forecasts of CaRFG3 properties. Given the importance of these property estimates to the waiver analysis, EPA utilized MathPro to perform additional modeling, and used these results to re-evaluate the potential emission effects of the oxygen waiver. Both the initial and the re-analysis are discussed in this section.

a. Previous analyses using results from early MathPro refinery modeling

The modeling that MathPro conducted for the California Energy Commission (CEC) considered several variants of the proposed California Phase 3 predictive model (PM3). These

variants differed in the reference fuel specifications incorporated into the model. As explained earlier, acceptability of a candidate recipe under the predictive model depends on emissions equivalency between the candidate recipe and the reference fuel. An acceptable fuel must show equivalency for all pollutants-hydrocarbons and toxics as well as NOx. The refinery model sought an economic optimum, subject to various resource constraints, for a refinery operation which produced, among other products, fuel which meets California Phase 3 predictive model performance requirements. The refinery model estimated the predictive model input parameters for the gasoline production modeled and included a version of the predictive model so that emissions performance constraints could be applied to the CaRFG portion.

One series of cases, the cases designated as "2" in the CEC MathPro study assumed a reference fuel ("Reference fuel B") with properties of the proposed flat limit recipe, including the 6.9 psi optional RVP limit. At the time of the report, the reference standards for CaRFG3 had not been adopted. Subsequent to the report, CARB staff recommended a change in the T50 standard (from 211 F to 213 F) but made no other changes. Based on past performance, we anticipated that most California refiners would produce California reformulated gasoline using the flat limits in the predictive model.[34] Since Reference Fuel B most closely represented the flat limit recipe that we expected to be codified, we believed that, among the cases modeled in the MathPro CEC report, results from the "2" cases were likely to predict the fuel properties for CaRFG3 most accurately.

In order to quantify the net NOx-oxygen effect as well as the VOC and CO effects associated with granting the waiver, we needed, as a basis for comparison, an estimate of

[34] The CARB Phase 3 staff report (October 22, 1999), cited earlier states on page 6 that about 75 percent of all California gasoline at this time is being made using the flat limits.

CaRFG3 properties in a "no-waiver" scenario. MathPro modeled cases in which ethanol is blended at 2.0 weight percent and 2.7 weight percent oxygen. Although the federal RFG oxygen per-gallon standard is 2.0 weight percent, ethanol has traditionally been blended in federal RFG at 10 volume percent ethanol (about 3.5 weight percent oxygen), in order to take full advantage of tax incentives. As discussed earlier, the complex model shows a decrease in NOx with increasing oxygen. Thus, compliance with the federal NOx performance standard does not constrain the amount of oxygen that can reasonably be used in federal RFG. California's PM3, however, shows an increase in NOx with increasing oxygen (at a much higher rate than PM2). The PM3 NOx-oxygen relationship is also non-linear, with the rate of NOx increase increasing directly with fuel oxygen content. This response effectively limits the amount of oxygen that can used in CaRFG3, because substantial changes in other fuel parameters must be made to compensate for the NOx increase associated with an increase in oxygen.[35] MathPro's December 7, 1999 report noted that its refinery model could not produce a complying gasoline at 3.5 percent oxygen. Although MathPro's model did find a feasible 2.7 percent oxygen fuel, we selected the 2.0 percent oxygen fuel described in the report as "Case 2a CARB" to represent the "no waiver" case. We believed at the time that selection of the 2.0 percent fuel as the basis for comparison was appropriate because this oxygen level is the oxygen content standard for Federal RFG. Furthermore, we felt that selection of a 2.0 percent oxygen fuel as the basis for comparison

[35] For example, while holding other PM3 parameters at the phase 3 flat limit values, increasing oxygen from 2.0 to 2.7 percent would require about an 11 ppm sulfur reduction (from 20 to 9 ppm) to maintain the same NOx emissions. If oxygen were increased an additional 0.7 weight percent from 2.7 to 3.4 percent, reducing sulfur to 0 ppm would still not fully compensate for the NOx increase due to oxygen.

was likely to provide a more severe test of the hypothesis that there is a NOx benefit associated with oxygen removal.[36]

The CEC MathPro study described a series of cases in which the CaRFG3 production was split between fuel oxygenated with ethanol at 2.7 weight percent oxygen and non-oxygenated fuel. MathPro did not report fuel properties for split market cases in which the oxygenated portion of fuel was produced with 2.0 weight percent oxygen.

As explained earlier, we elected to use a set of fuel properties with oxygen at 2.0 percent to represent CaRFG3 in a "no-waiver" case. We had no clear indication that, if a waiver were granted, the portion of gasoline produced with oxygen would be oxygenated at a substantially different oxygen level than in a "no waiver" case. In the absence of such evidence, we were reluctant to assume a 2.7 percent oxygen level in the oxygenated CaRFG3 in a split market. (Again, the increasingly steep NOx response to oxygen limits oxygen content.) If we were to incorrectly assume a higher oxygen content for "waiver case" CaRFG3 than "no waiver" CaRFG3 we would likely underestimate the NOx emission benefit attributable to the waiver. On the other hand, we do not believe that, if a waiver were granted, any significant amount of oxygenated CaRFG3 would be produced with less than 2 percent oxygen. Suppliers will be motivated to use more than 2.0 percent oxygen in order to take advantage of the PM3 CO credit and the federal ethanol tax credit. Noting the uncertainty about the oxygen content of CaRFG3 in a split market, we elected to assume that it would be at 2.0 percent.

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[36] This assumes that a fuel with 2.7 percent oxygen has poorer NOx performance than a fuel with 2.0 percent oxygen. We could possibly reach that conclusion even if comparing a 2.0 percent oxygen and a 2.7 percent oxygen fuel with equivalent PM3 NOx performance because we employed different modeling assumptions and considered non-road NOx emissions.

Ideally, for our purposes, CEC MathPro's modeling would have included cases where the market was split between 2.0 percent oxygen CaRFG3 and non-oxygenated CaRFG3. In the absence of such cases, we assumed that the properties of oxygenated CaRFG3 in a split market "waiver case" were those estimated for case 2a, our "no waiver" case. We also assumed that the properties of non-oxygenated CaRFG3 would be the same as those of non-oxygenated California fuel in a 2.7 percent oxygen/non-oxygenated split market. We selected the properties that MathPro estimated for non-oxygenated CaRFG3 in the split market case, designated in the report as "case 2e CARBno". The predictive model parameters of these two fuels are shown in Table 11.[37]

Table 11: Predictive model parameters of the two fuels in the December 7, 1999 analysis (for California Energy Commission)

Property	Case 2a CARB	Case 2e CARBno
RVP (psi)	6.6	6.6
Oxygen (wt percent)	2.0	0.0
Aromatics (vol percent)	24.2	19.3
Benzene (vol percent)	0.55	0.50
Olefins (vol percent)	3.3	5.7
Sulfur (ppm)	10.4	23.1
T50 (○F)	208	199
T90 (○F)	303	310

The above parameters are estimates of actual fuel properties. This takes into account that refiners allow compliance margins for various properties to ensure that measurements of these

[37] See Exhibit 4 in the December 7, 1999 MathPro report for more extensive property summaries for these and other cases.

properties in samples do not exceed recipe specifications. The California Energy Commission specified compliance margins to be used in this modeling. These compliance margins, if added to the above properties, yield the specifications for the fuel.[38] These resultant specifications must satisfy the predictive model's emissions performance criteria to be allowed by the refinery model.

Table 12 presents the net NOx difference between the non-oxygenated and the oxygenated CEC MathPro fuels (using the actual properties shown above) estimated by the composite PM3, each component of PM3, and EPA's alternative Tech 4 NOx models discussed earlier. The percent change in NOx emissions when oxygen is changed from 0 to 2 percent with other properties held constant at CARFG3 flat limits was shown earlier in Table 10. These "flat limit" responses are repeated here for comparison.

[38] The compliance margins specified by CEC are listed in Table D of the MathPro report. For example, the RVP specification for the fuels shown above would be 6.6+0.22=6.82 psi.

Table 12: NOx Emission Change from adding 2 percent Oxygen to Fuel (values in %)

Percent change in NOx emissions for increase from 0 to 2 % oxygen		
Model	MathPro Fuels	Other Properties @ CA RFG3 Flat Limit Values (from Table 10)
PM3-composite	0.26	1.91
PM3-Tech 3	5.12	2.83
PM3-Tech 4	1.57	1.79
PM3-Tech 5	-1.66	1.79
EPA “Tech 4" models:		
6	5.20	5.23
5	5.15	4.84
10	4.91	4.82
Step-3	4.76	5.29
Step-2	4.21	4.87
Step-1	2.32	2.91
3	2.31	3.07
Step-4	2.28	3.20
Step-5	2.04	3.16
7	1.78	2.80
CARB	1.32	1.42
RB-3	-0.33	0.64

Comparison of the CEC MathPro to the flat limit responses did show that changes in other properties resulting from changes in oxygen level are likely to have some impact on net NOx emissions percent change. For example, the higher sulfur and olefin levels for the MathPro non-oxygenated CARFG3 tended to oppose the effect of oxygen removal on NOx emissions, since these models predict that NOx will increase as these parameters increase. This is most apparent in the PM3 Tech 5 model, where the change in NOx emissions with change in oxygen is similar to that of Tech 4, but the change in NOx emissions with change in sulfur is greater.[39] Except for the Tech 5 component of the PM3, and the RB-3 model, however, the responses are

[39] The substantial uncertainties associated with the Tech 5 model due to lack of underlying data have been discussed.

directionally consistent with the flat limit responses. They show that, even when other property effects are considered, an increase in oxygen content is likely to result in an increase in NOx emissions. Conversely, a decrease in oxygen content is likely to result in a NOx decrease. Furthermore, comparison of results from EPA's alternative models with the PM3 Tech 4 result suggests that the PM3 Tech 4 model may underestimate the net NOx effect. EPA's "preferred" models all show a larger NOx increase than the PM3 Tech 4 model.[40]

Based on the average CEC MathPro fuel response from our "preferred" models (6,5, Step-3, Step-2, 3 and 7), we estimated that an increase from 0 percent to 2 percent oxygen would result in a 3.90 percent increase in NOx emissions from Tech 4 vehicles switching from non-oxygenated to oxygenated CaRFG3. There would be a corresponding decrease in NOx emissions of -3.74 percent resulting from a decrease in oxygen content of 2 percent to 0 percent by weight. We used this number (the FACTOR), in conjunction with other information, to estimate the effect of the waiver on Tech 4 NOx emissions. [41]

Analysis based on these CEC MathPro fuels indicate that a change in oxygen content from 0 to 2 percent would result in an increase in NOx emission of 5.12 percent in Tech 3 vehicles. Correspondingly, a decrease in oxygen from 2 percent to 0 percent would be accompanied by a decrease in NOx emissions of -4.88 percent in these vehicles. We used this

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[40] See the earlier discussion of the model selection process, in which EPA identified some of the alternative models as better than others. The CARB and RB-3 models, the two models which did not show a larger increase in NOx, were not among the preferred models.

[41] We used an estimate of 289.45 tons/day NOx to represent on-road gasoline vehicle South Coast NOx emissions in 2005 without a waiver. We apportioned these emissions to the three Tech groups using factors from the PM3 (12.2% to Tech3, 34.8% to Tech4 and 53.0% to Tech5). We multiplied our estimate of Tech4 NOx emissions in 2005 (100.73 tons/day) by our estimate of the non-oxygenated market penetration with a waiver (40%) by the "2 percent to 0 percent FACTOR" (-3.74%) yielding a 1.50 ton/day reduction.

FACTOR, in conjunction with other information, to estimate the effect of the waiver on Tech 3 NOx emissions. [42]

The CEC MathPro 0 percent to 2 percent oxygen fuel response from the Tech 5 component of PM3 is a 1.66 percent decrease in NOx. This response is directionally different than the "flat limit" response in which only oxygen was varied. As stated earlier, the sulfur effect on NOx is much greater in the Tech 5 model than in the Tech 4 model. Our selection of the specific MathPro modeling cases to represent non-oxygenated and oxygenated CaRFG3 results in non-oxygenated CaRFG3 with higher sulfur content than oxygenated CaRFG3. This is contrary to the sulfur content relationship shown in CARB's December 24, 1999 letter.[43] (While reductions in sulfur could help offset increases in PM3 exhaust HC emissions resulting from oxygen removal, oxygen removal also reduces PM3 NOx emissions, potentially allowing increases in sulfur.) Thus, in addition to significant doubts about the accuracy of the Tech 5 model due to lack of underlying data, we are uncertain about the directional change in sulfur content, the fuel parameter which becomes substantially more important in these newer vehicles. Since we are currently unable to resolve these areas of uncertainty, we have assumed, for evaluation of this waiver request, that the net effect of changes in fuel oxygen content on Tech 5

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[42] 35.31 tons/day x 40% x (-4.88%) yielding a 0.69 ton/day reduction

[43] In CARB's December 24, 1999 submittal see Table 2, "Example Fuel Properties", and Table 3, "Example Future In-Use Fuels", both showing lower sulfur in the zero oxygen fuel then in the 2 percent oxygen fuel. (In Docket A-2000-10, Document II-D-6 also available at http://www.arb.ca.gov/cbg/Oxy/wav/122499.pdf). In the EPA MathPro modeling, the sulfur in the zero oxygen CaRFG3 was either lower or higher than the sulfur in the non-waiver oxygenated CaRFG3l, depending on the scenario. In this modeling, the sulfur in the oxygenated fuel with the waiver also differed from the sulfur in the oxygenated fuel without the waiver in most scenarios. When sulfur differences in both the oxygenated and non-oxygenated portions of the CaRFG3 pool are considered, the market-share weighted net sulfur difference between waiver and no waiver CaRFG3 is small (<3 ppm in all scenarios).

NOx emissions is zero. We believe that, in the absence of other fuel property changes, engineering judgement would support this assumption. The more sophisticated engine management and fuel control systems in these newer vehicles are likely to reduce the effects of fuel oxygen on combustion. Thus, we would expect that both engine-out and post-catalyst emissions would be less sensitive to the changes in fuel oxygen content. Although we cannot extend this conclusion to changes in other parameters, particularly sulfur, we believe that the higher degree of uncertainty associated with the Tech 5 model, and the greater potential for error introduced by incorrectly forecasting fuel sulfur changes, points to this zero-effect assumption as the best compromise. Even if the sulfur effect is not small, however, the EPA MathPro modeling suggests that the sulfur changes are likely to be small. Thus, the zero effects assumption, even if it is erroneous, is unlikely to introduce a substantial error in EPA's analysis.

b. Results of most recent analysis

The CEC MathPro modeling did not use a finalized version of the phase 3 predictive model and we were unsure if subsequent changes to reference specifications would have substantially affected the modeling results. We elected to compare "waiver" and "no waiver cases" where oxygenated CaRFG3 was oxygenated at 2.0 weight percent. The CEC MathPro modeling, however, only included split market cases where the oxygenated CaRFG3 was assumed to be oxygenated at 2.7 weight percent. Consequently, in the earlier analysis, we selected a single set of fuel properties, estimated for a 100 percent ethanol market share at 2.7 weight percent, to represent 2.0 weight percent oxygenated CaRFG3 for both the 100 percent ethanol "no waiver" and split market "waiver" conditions. We retained the property estimates from a split market case to represent the non-oxygenated portion of the CaRFG3 pool.

The assumption of the same properties for oxygenated CaRFG3 with and without a waiver simplified our previous analysis of emission effects. Under this assumption we needed to consider only the NOx exhaust emissions changes occurring because a portion of the "no waiver" oxygenated CaRFG3 pool would be replaced by non-oxygenated CaRFG3. The properties of oxygenated CaRFG3, however, are likely to differ under "no waiver" and "waiver" conditions. Thus, our previous analysis ignored the potential exhaust emissions changes occurring because a portion of the "no waiver" oxygenated CaRFG3 would be replaced by "waiver" oxygenated CaRFG3. Furthermore, we would expect that the refiners' decisions regarding how to formulate non-oxygenated gasoline under a waiver could be affected by the how they formulate the oxygenated portion of the CaRFG3. Our use of non-oxygenated CaRFG3 properties from a 2.7 percent/non-oxygenated refinery modeling case to represent non-oxygenated CaRFG3 in a 2.0 percent/non-oxygenated split market could therefore also introduce error in our estimate of emissions effects. Additionally, we were uncertain about the oxygen weight content that would be used in ethanol-oxygenated CaRFG3 with and without a waiver. Thus it was unclear that our assumption of a 2.0 percent oxygen level in oxygenated CaRFG3 with and without a waiver represented the most likely scenario.

Consequently, EPA commissioned MathPro to further investigate, through refinery modeling, the issues of non-oxygenated market share, fuel property values, and oxygen content for CaRFG3 if the oxygen requirement were waived with an MTBE ban in place. (Previously cited in Section III.B.2.b.; available in Docket A-2000-10, Document Number II-D-66). EPA also required, for comparison purposes, an estimate or estimates of fuel property values for

CaRFG3 if a waiver were not granted (i.e., 100 percent ethanol-oxygenated CaRFG3 in federal areas).

EPA believes that this additional MathPro modeling provides an improved forecast of the potential characteristics of CaRFG3 under "waiver" and "no waiver" conditions because:

1. This analysis incorporated the Beta 3 (final) version of the predictive model and flat limit reference specifications.
2. This analysis incorporated estimates of prospective supplies and prices of crude oil and blendstocks "imported" (from outside of California) blendstocks which were revised to reflect more recent market conditions and forecasts.
3. The MathPro linear programming refinery model incorporated newly-obtained technical information that may have affected the relative economics of ethanol blending at 2.0 weight percent and 2.7 weight percent and the "optimal" shares of oxygenated and non-oxygenated CaRFG3.

As noted in the discussion of market penetration, the EPA MathPro modeling investigated a number of cases in which refiners blended CaRFG3 with and without a waiver using the phase 3 predictive model, the flat limit reference specifications, and the exhaust plus evaporative VOC compliance option. In these cases the impact of various factors was considered. Specifically, we evaluated the properties of CaRFG3 where oxygen was used at 2.0 percent or 2.7 percent by weight, the constraints of the Unocal patent were imposed (requiring refiners to avoid the parameter ranges established by the patent, called "patent avoided") or eliminated (assuming, the patent did not lead to a change in the fuel formulation, for whatever reason, called "patent not avoided"), and where MTBE use outside of California was assumed to

be reduced (e.g., because of MTBE bans or refiner liability concerns) or assumed to continue at current levels. The CaRFG3 property values and market share information for these cases was shown in Table 11 in Section III.B.2: eight sets of fuel properties for which waiver-no waiver emissions comparisons can be made. We cannot rule out the possibility that refiners may elect to blend ethanol-oxygenated CaRFG3 at different oxygen content under waiver and no waiver conditions. Thus we have sixteen possible waiver-no waiver NO_x emissions comparisons. These possible comparisons are illustrated in the tree diagram shown below (Figure 1).[44]

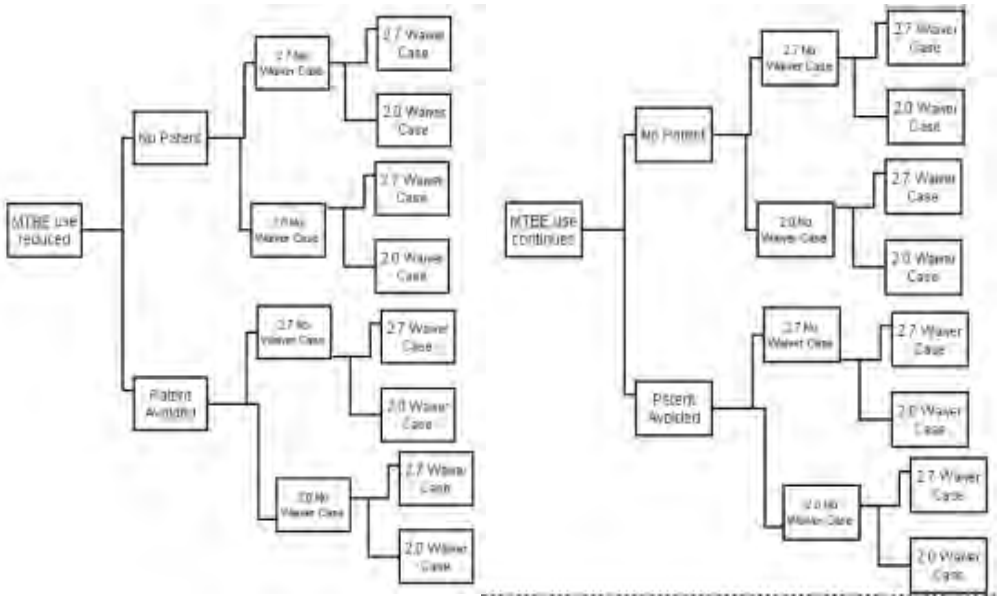
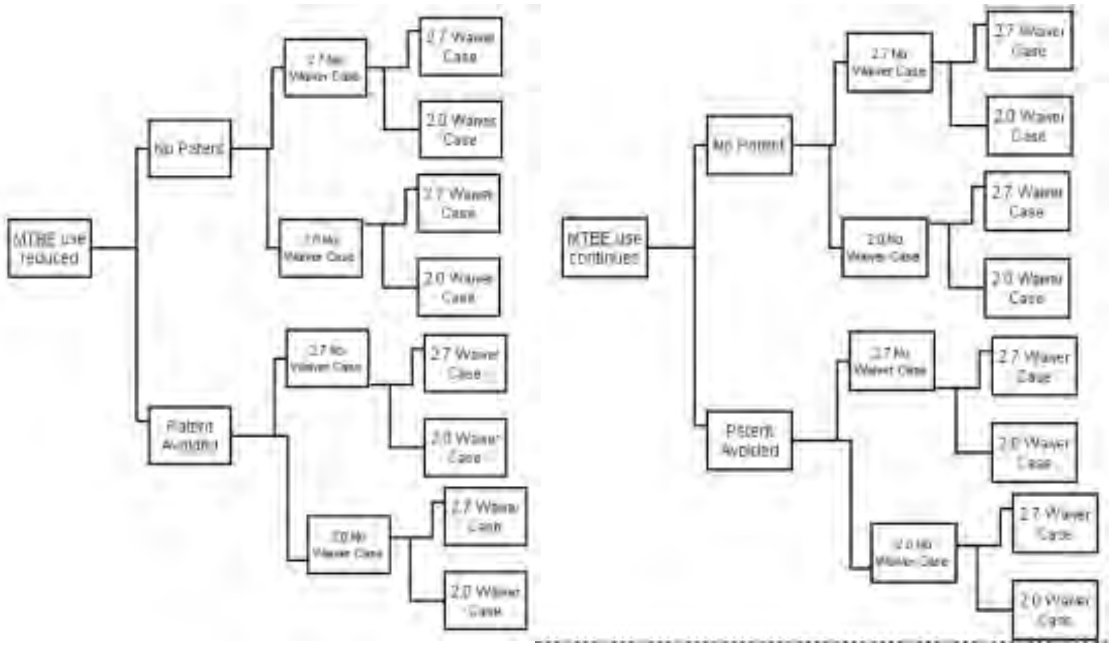


Figure 1

[44] The tree diagram uses the term "no patent", consistent with the MathPro report, to describe those cases where the constraints of the Unocal patent are not avoided. The term "no patent" means that the predicted properties for the blends could fall within the patent ranges. MathPro did not assign additional costs for producing such blends. In subsequent sections of this document EPA has used the term "patent not avoided" to identify those scenarios. The Patent Office is still being asked to reconsider their patent decision. Some refiners may choose pay a premium to produce gasoline within the constraints of patent. MathPro's modeling did not study the effect of a premium on patented gasoline.

As noted previously, MathPro's analysis for EPA concluded that, in the "waiver" cases, the relative economics of blending to 2.0 percent and 2.7 percent oxygen are too close to call. MathPro also concluded that there was a small, but significant advantage to use of 2.7 percent oxygen in the "no waiver" cases. MathPro's modeling, however, was an aggregate analysis of California refining. The economics for a given refinery might favor blending at 2.0 percent in a "no waiver" case, depending on its technology. Additionally, since MathPro characterized the advantage of 2.7 percent in the "no waiver" cases as small, this advantage is likely to be highly sensitive to the technical and economic assumptions used in the modeling. Consequently, EPA believes that within this subset it is reasonable to consider both 2.7/2.7 and 2.7/2.0 "no waiver"/"waiver" comparison scenarios. We assume that those refineries which, because of their configuration, would choose to blend at 2.0 percent oxygen in a "no waiver" case would also likely choose to blend at 2.0 percent in a "waiver" case. Therefore, we have



ignored the four 2.0/2.7 “no waiver”/”waiver” comparison scenarios since we do not expect these scenarios to represent the overall CaRFG3 pool, or any subset of California refiners.

We previously identified a set of “preferred “ alternative Tech 4 NOx models (6,5, Step-3, Step-2, 3 and 7) and elected to average the response of those models to derive a percent change FACTOR to utilize in our emission estimates. Table 13 shows the average estimated NOx percent change from non-oxygenated “waiver” fuel to oxygenated “no waiver” fuel for the twelve comparison scenarios evaluated. This table also shows the average estimated NOx percent change from oxygenated “waiver” fuel to oxygenated “no waiver” fuel.

Table 13: EPA Tech 4 Model “Waiver” to “No Waiver” NOx Percent Changes

No Waiver Oxy level	Waiver Oxy level	Nationwide MTBE Use	Unocal Patent	Percent NOx Change non-oxy to oxy (no waiver)	Percent NOx Change oxy (waiver) to oxy (no waiver)
2.0	2.0	Reduced	Patent not avoided	3.80	1.17
2.7	2.7	Reduced	Patent not avoided	5.41	0.79
2.7	2.0	Reduced	Patent not avoided	5.28	2.62
2.0	2.0	Continues	Patent not avoided	4.47	0.02
2.7	2.7	Continues	Patent not avoided	5.18	0.09
2.7	2.0	Continues	Patent not avoided	5.96	1.45
2.0	2.0	Reduced	Patent avoided	4.46	-0.52
2.7	2.7	Reduced	Patent avoided	6.17	0.24
2.7	2.0	Reduced	Patent avoided	6.47	1.39
2.0	2.0	Continues	Patent avoided	4.54	-0.14
2.7	2.7	Continues	Patent avoided	5.95	0.46
2.7	2.0	Continues	Patent avoided	6.55	1.78

This table shows that, for each comparison, Tech 4 vehicle NOx emissions increase with increasing oxygen. This is true not only for the non-oxygenated to oxygenated fuel changes, but for the oxygenated to oxygenated fuel changes where the oxygen level is higher in the "no waiver" fuel. These factors, inverted to give "no waiver" to "waiver" changes, were used to estimate the effect of the waiver on Tech 4 NOx emissions. This calculation was done in the same basic manner as in our earlier analysis. In this analysis, we used the oxygenated and non-oxygenated market shares associated with each specific case, apportioned the inventory according to these market shares, and applied the appropriate change FACTOR.

As in our earlier analysis, we estimated Tech 3 NOx emission changes using the Tech 3 portion of the Phase 3 predictive model. The "waiver" non-oxygenated to "no waiver" oxygenated changes ranged from 0.40 to 4.19 percent, all showing a net NOx increase with oxygen. The "waiver" oxygenated to "no waiver" oxygenated changes were mixed and ranged from -2.81 percent to 3.15 percent. As before, we assumed no fuel-related emission effects for the Tech 5 vehicles. The resultant emission changes are shown in Table 14 below, with a negative number indicating a reduction in emissions with a waiver.

Table 14: Estimated South Coast On road NOx Emission Inventory Changes With Waiver (tons/day)

No Waiver Oxy Level	Waiver Oxy Level	Nationwide MTBE Use	Unocal Patent	NOx emission change from no waiver scenario
2.0	2.0	Reduced	Patent not avoided	-3.26
2.7	2.7	Reduced	Patent not avoided	-3.64
2.7	2.0	Reduced	Patent not avoided	-4.67
2.0	2.0	Continues	Patent not avoided	-2.51
2.7	2.7	Continues	Patent not avoided	-2.08
2.7	2.0	Continues	Patent not avoided	-3.93
2.0	2.0	Reduced	Patent avoided	-3.40
2.7	2.7	Reduced	Patent avoided	-3.58
2.7	2.0	Reduced	Patent avoided	-5.56
2.0	2.0	Continues	Patent avoided	-2.27
2.7	2.7	Continues	Patent avoided	-2.51
2.7	2.0	Continues	Patent avoided	-4.45

C. Foreseeable effects of reduced oxygen on other pollutants and off-road vehicles in California

1. Quantification of oxygen/VOC effect

When gasoline oxygen content decreases, all else constant, exhaust hydrocarbon emissions are expected to increase. Table 15 shows the percent change in exhaust hydrocarbons emissions estimated by various models when oxygen content is changed from two percent to zero percent while other properties are held at California Phase 3 flat limits.[45] CARB's predictive

[45] A similar table for NOx was shown in Section III.A.5.c. (Table 9) See the explanatory note regarding comparison of results from different models.

models and EPA's complex model predict that HC emissions will increase with decreasing oxygen, all else constant.

Table 15: Estimated Percent Change in Exhaust HC for Oxygen Content Change from 2% to 0% (Other properties at Ca Phase 3 flat limits)

Model	Percent Change in Exhaust HC (positive indicates increase)
PM3-Tech 3 only	4.45
PM3-Tech 4 only	2.84
PM3-Tech 5 only	2.97
PM3-composite	3.15
PM2-Tech 3 only	4.48
PM2-Tech 4 only	2.24
PM2-composite	2.69
Phase II Complex Model	0.73

Since reducing the oxygen content may adversely affect hydrocarbon emissions, elimination of the oxygen mandate could potentially result in a reduction in NOx emissions with a concurrent increase in VOC emissions. This VOC increase could reduce or negate the ozone benefit occurring from the NOx decrease. As with NOx, however, the net effect of oxygen removal on VOC emissions depends not only on the change in oxygen content, but on the changes in other fuel properties that would occur with the oxygen content change. Thus, quantifying the net effect of an oxygen content waiver on VOC emissions depends on the selection of the model or models which may reasonably represent the relationship between VOC emissions and fuel properties, as well as the same fuel property and non-oxygenated market penetration considerations applicable to the oxygen/NOx analysis. Since EPA had some of the

same concerns with CARB's VOC modeling as with their NOx model, we decided to independently examine the relationship between the fuel properties and VOC emissions in much the same way as was done with NOx.

EPA, through its consultant, investigated alternative hydrocarbon models for the Tech 4 portion of the California fleet. Unlike the CARB Tech 4 model, in which the dependent variable in the regression was total exhaust hydrocarbons, the alternative models developed by EPA's consultant used non-methane hydrocarbons (NMHC) as the dependent variable. A NMHC model should better estimate the vehicle emissions regulated in California. The selection of NMHC as the dependent variable resulted in the exclusion of a substantial amount of data, since this value was not reported for all emission tests in the predictive model database.[46] EPA believes that the objective of accurately modeling the emissions components controlled by California regulatory efforts outweighed the loss of data. Some of the data from the original set were excluded for other reasons as well. The specific exclusions and the reasons for them are detailed in the EPA consultant's report (See Docket A-2000-10, Document Number II-D-63: "Building the NMHC Model," Work Assignment No. 2-9, Contract 68-C-98-169, SwRI Project 08.04075; December 20, 2000) and generally parallel similar decisions made when modeling NOx emissions, as discussed earlier. CARB excluded data from four studies on grounds that the vehicles involved in the studies were "high influence" vehicles. EPA elected to retain the data from these vehicles on grounds that our use of a "high-emitter" term would permit the model to adequately incorporate the effects of these data without distortion.

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[46] Had EPA built a total exhaust HC model the sample size would have been 7031 tests, the number of observations used for the NOx model. The NMHC model sample size was 5441 tests.

a. Statistical Methodology.

In most respects the statistical approach used in developing EPA's Tech 4 NOx emissions models was also followed in modeling NMHC: A "mixed effects" statistical model was used, as described earlier in connection with the NOx modeling. Until recently, this type of model could not be used with large datasets because of the computational intensity and the lack of appropriate software. Such a mixed effects model made it possible to treat the fuel effects as fixed effects, while handling vehicle effects as if the vehicles had been sampled from some larger population of vehicles.

As has been done in almost all statistical analysis of vehicle emissions data of this sort,[47] the dependent variable was subjected to a log transformation to correct the strong positive skew in the distribution of NMHC and to make it possible for the dataset to meet certain basic requirements for the use of most regression techniques.[48] After data deletions, the seven fuel properties' values were standardized so that each had a mean of zero and a standard deviation of one. This was done to hold down the size of the coefficients. Table 16 lists the information needed to destandardize model coefficients.

Table 16 Means and Standard Deviations of Fuel Properties

Fuel Term	Mean	Standard Deviation	Sample Size
RVP	8.509825	0.781459	5441
T50	205.616633	17.612534	5441
T90	310.646370	20.869732	5441

[47] EPA's Complex Model development and CARB's modeling of fuel effects are examples of this.

[48] Use of regression requires the assumption that the variance of the dependent variable not differ substantially for different fixed regions of the independent variable(s). This assumption, termed "homoscedasticity", cannot easily be met by a dependent variable that is strongly skewed without a corrective transformation.

AROM	27.635030	6.561886	5441
OLEF	6.927366	5.143184	5441
OXYGEN	1.492613	1.249356	5441
SULFUR	183.142492	143.055894	5441

Repeat tests on the same vehicle with the same fuel were retained as distinct observations in the dataset in order to preserve and account for all of the sources of variation in the dependent variable. Finally, a categorical variable was introduced into the dataset to differentiate high-emitting vehicles from normal emitters. This last procedure requires some further discussion.

In their NOx model, CARB elected not to incorporate a high-emitter dummy variable both because their preliminary analysis showed such a variable to be capable of explaining relatively little variance, and also because of the potential statistical difficulties involved in having NOx emissions on both sides of the regression equation, i.e., in both the dependent variable and in some of the independent variables.[49] EPA, when modeling NOx, chose to include a high-emitter variable, but one defined in terms of hydrocarbon and/or CO emissions rather than in terms of NOx, as was done in the CARB analysis. This choice was based on engineering reasoning–that the NOx emissions of vehicles with damaged catalytic convertors or impaired air/fuel ratio control (and, therefore, high hydrocarbon and/or CO emissions) might respond differently to changes in fuel composition than the emissions of vehicles in which these systems were intact. By defining high-emitters in terms of HC/CO, the statistical problem of having some measure of NOx emissions in both the dependent variable and, in a different form, in some of the independent variables was avoided. When modeling NMHC, though, the statistical

[49] The specific difficulty involves a pattern of complex correlations between the high-emitter dummy variable (coded “0" for normal emitters and “1" for high emitters) and the error term of the particular model.

problem is not so easily avoided, and some measure of hydrocarbon emissions is present in both the dependent variable and the high-emitter categorical variable. We decided that the possibility of learning something new about effects on the emission behavior of high emitters outweighed the possible statistical problems.[50]

The terms made available to the model-building process included the seven fuel properties, the squares of the seven properties (to allow for non-linear effects), the two-way interactions among the seven, the high-emitter term, and the seven interactions between the high-emitter term and the fuel properties. Thus 43 terms were considered statistically for possible inclusion in the models that were developed.

The consultant applied a stepwise procedure, as with the NOx models, to select terms for inclusion in the model. The seven linear terms were forced into the model first. Then the stepwise procedure introduced other candidate terms in order of their potential to explain NMHC variance. After each new term was introduced, the status of non-linear terms already in the model was examined to see if any of them were no longer statistically significant at the 0.05 level and should thus be removed–no such removals proved to be necessary. Tables 17 and 18 present the models that resulted from the straightforward stepwise analysis.[51]

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[50] High emitters were defined as vehicles whose average emissions of total hydrocarbons (THC) exceeded 0.82 gram per mile and/or whose average carbon monoxide (CO) emissions exceeded 6.8 grams per mile. About 13 percent of the vehicles involved in the NMHC modeling effort were defined as high emitters by this criterion. This percentage should not be taken to be an estimate of either the fleet proportion of high emitters or the fraction of emissions that are due to high emitters, since the vehicles included in this dataset are not a random or probabilistic sample of vehicles from the in-use fleet.

[51] The coefficients in bold italics were not statistically significant at the 0.05 level in the model where they occur. This can happen for a variety of reasons. In the case of the Step 0 model in Table 14, the RVP term is not statistically significant (and, incidentally, is not statistically significant in several of the other models). Since we forced the term into the equation rather than allowing the stepwise process to select it, its non-significance should not be surprising. The other

Table 17: Estimated Standardized Coefficients for First Half of Stepwise Regression Fit to Log(NMHC) (Bold italics indicate non-significant terms at 0.05 significance level)

Standardized							
Term	Step 0	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Intercept	-1.2801	-1.5610	-1.5687	-1.5814	-1.5886	-1.5837	-1.6014
RVP	*0.008740*	0.01102	*0.006418*	***0.007653***	0.01206	0.01253	*0.007147*
T50	0.04687	0.04991	0.04072	0.05697	0.06454	0.06525	0.06042
T90	0.02168	0.02064	0.03167	0.02465	0.02068	0.02023	0.02143
AROM	0.01411	0.01302	0.02050	0.01538	0.01382	0.01379	0.01049
OLEF	-0.01522	-0.01491	-0.02153	-0.01850	-0.01548	-0.01522	-0.01570
OXYGEN	-0.01673	-0.01545	-0.01991	-0.01244	-0.00875	*-0.00815*	-0.01351
SULFUR	0.04645	0.04337	0.04120	0.04363	0.04575	0.05343	0.05441
HI-EMIT		1.7080	1.7040	1.7055	1.7073	1.6903	1.6914
T90*T90			0.02570	0.02000	0.01851	0.01844	0.01840
T50*T50				0.02036	0.02836	0.02853	0.02899
T90*OXY					0.01680	0.01713	0.01817
SUL*HI						-0.03006	-0.03043
OXY*OXY							0.01470

Table 18: Estimated Standardized Coefficients for Second Half of Stepwise Regression Fit to Log (NMHC) (Bold italics indicate non-significant terms at 0.05 significance level)

Standardized				
Term	Step 7	Step 8	Step 9	Step 10
Intercept	-1.5957	-1.5980	-1.6038	-1.6039
RVP	*0.008474*	*0.008971*	0.01064	0.01173
T50	0.06125	0.06499	0.06545	0.06376
T90	0.02084	0.02104	0.02188	0.02421
AROM	0.008729	*0.008465*	0.01032	0.01070
OLEF	-0.01426	-0.01430	-0.02481	-0.02657
OXYGEN	-0.01329	-0.01378	-0.01444	-0.01560
SULFUR	0.05505	0.05495	0.05697	0.05630
HI-EMIT	1.6909	1.6935	1.6939	1.6937
T90*T90	0.01617	0.01604	0.01444	0.01515
T50*T50	0.02494	0.02477	0.02523	0.02383

reason for some of the non-significant terms is illustrated by the Step 3, Step 4, and Step5 models. Oxygen was a significant and strong predictor in the Step 3 model, but when the T90*OXY interaction term came in on Step 4 the coefficient for oxygen became much smaller. By the Step 5 model, the oxygen coefficient is smaller yet and has become non-significant, the variance that it initially explained taken over by other terms, most prominently an interaction term involving oxygen.

T90*OXY	0.01589	0.01576	0.01595	0.01519
SUL*HI	-0.03174	-0.03172	-0.03141	-0.03123
OXY*OXY	0.01256	0.01353	0.01393	0.01367
T90*ARO	0.006908	0.007013	0.007963	0.008756
T50*HI		-0.02609	-0.02579	-0.02529
OLEF*OLEF			0.006272	0.007654
T90*OLEF				-0.00400

After Step10 there were no additional terms that had potential to explain NMHC emissions, and so the "stepwise" process stops there. "Measures of fit" were computed for the eleven models resulting from the stepwise process. These measures are presented in Table 19, below.

Table 19. Measures of Fit for Models From Stepwise Regression Fit to Log(NMHC)

Step	No. of Terms	Added Fuel Term	AIC	BIC	RMSE	Vehicle Error
0	7	7 Linear	1013.7	995.0	0.1287	0.8526
1	8	HI-EMIT	1353.2	1334.5	0.1288	0.4978
2	9	T90*T90	1409.4	1386.1	0.1263	0.5002
3	10	T50*T50	1452.6	1426.9	0.1248	0.5006
4	11	T90*OXY	1470.8	1442.8	0.1241	0.5002
5	12	SUL*HI	1470.1	1439.8	0.1241	0.5013
6	13	OXY*OXY	1485.8	1453.1	0.1237	0.4986
7	14	T90*ARO	1507.6	1472.6	0.1227	0.4984
8	15	T50*HI	1506.7	1471.7	0.1226	0.4982
9	16	OLEF*OLEF	1504.0	1469.0	0.1227	0.4980
10	17	T90*OLEF	1501.1	1466.2	0.1226	0.4978

The measures presented in the table are indicators of the information content of the models and of the extent to which the models serve to reduce errors in predicting NMHC emissions.[52] The AIC and BIC indicators, measuring different aspects of the models' fit, together indicate a kind of "peak" in the stepwise process beyond which additional terms are not adding

[52] These statistical measures were introduced in the section discussing EPA's building of alternative Tech 4 NOx models. See Section IV.B.

significantly to the predictive utility of the model and may actually be "overfit", a condition in which the model is explaining variation in the sample data that is not likely to be seen upon resampling.[53]

EPA selected the "Step 7" model for further investigation, since this model showed the highest AIC and BIC values. Unlike the alternative NOx models which we investigated, this model contained a statistically significant property by high emitter interaction term; specifically a sulfur by high emitter term. (The NOx models contained a high emitter term but did not contain any high emitter interaction terms.) Thus, this model predicts that normal and high emitters would show a different NMHC response to changes in fuel sulfur. Consequently, when this model is used to evaluate the percent emissions difference between the zero oxygen and two percent oxygen MathPro fuels, which also differ in sulfur content, the result depends on the emitter status assumed. (The MathPro study which defines these fuels was previously cited in Section III.B.2.b. and is available in Docket A-2000-10, Document Number II-D-66.) The emitter status assumption does not affect the percent difference calculation when other properties, including sulfur, are held constant. Table 20, below, shows the "Step 7" model percent responses for the above cases, together with the PM3 Tech 4 responses:

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[53] To explain this another way, if we were to repeat the entire "experiment" multiple times (sample new vehicles, test them on the same fuels, and then go through the data preparation processes and model-building) some of the terms would be likely to appear in almost all of the resulting models, while others might appear very infrequently. It is, of course, wildly impractical to actually repeat the experiment, but statistical theory offers us some tools for differentiating between models that are likely to be successful at explaining variation in most such hypothetical experiments and those that might be unique to the particular experiment that was actually performed and thus poor predictors of the NMHC response to changing fuel parameters. Models emerging from the stepwise process after the peak values of AIC and BIC were reached are likely to be "overfit" in this sense and be poor predictors. Our attention should thus center upon models that are near the peak values of these measures.

Table 20: Estimated Percent Change in exhaust HC for Oxygen Content Change from 2% to 0%

Case	Percent Change in Exhaust HC (when oxy decreased from 2 to 0%: positive indicates increase)
Step 7 Model-Other properties constant at flat limits	4.50
Step 7 Model-MathPro CEC Fuels-High Emitters	0.45
Step 7 Model-MathPro CEC Fuels-Normal Emitters	0.74
PM3-Tech 4-Other properties constant at flat limits	2.84
PM3-Tech 4-MathPro CEC Fuels	0.04

Table 20 shows that the Step 7 model predicts a larger percentage change in exhaust emissions than the PM3 Tech 4 model for comparable fuel property changes. However, both models show substantially smaller effects for the MathPro CEC fuels than for the fuels where only oxygen was varied. Both models indicate that changes in other properties concurrent with changes in oxygen content could mitigate much of the hydrocarbon penalty associated with oxygen removal. EPA's consultant performed a variety of diagnostic and evaluative investigations on the Step 7 model, considering it to be representative of the better models that emerged from the stepwise process. Many of these checks involved examining the model's residuals[54] to look for outliers, to see whether any important statistical assumptions were violated by the model. These checks are presented in greater detail in the previously cited consultant's report ("Building the NMHC Model"; see Docket A-2000-10, Document Number II-D-63; Work

[54] Residuals may be thought of as prediction errors. The model being evaluated is used to predict the dependent variable (NMHC, in this case) as a function of the fuel properties. This predicted NMHC value is compared to the actual NMHC value, and all of these differences are analyzed to see if there are patterns which indicate problems with the fit of the model to the data.

Assignment No. 2-9, Contract 68-C-98-169, SwRI Project 08.04075). None of the checks indicated the presence of important problems with the model's fit or violations of assumptions.

b. Consideration of Alternative Models

There were two sources for alternatives to the stepwise models when modeling NMHC emissions. The first of these was to apply the "random balance" technique to models that were obtained by other means, primarily the stepwise process, to see if the existing models could be simplified. This technique, used in building the EPA Complex Model and applied at various stages of CARB's work, may succeed in simplifying an existing model when it will be used to make predictions within a particular fuel parameter space. Random balance was applied to the Step 7 model. None of the non-linear terms were eliminated, and the only effect was to disqualify the linear RVP and T90 terms, which were left in for reasons discussed in Section III.A.

The second source for alternative models was to examine the stepwise process looking for terms that were close competitors for entry into the equation at various steps, but which had a marginally higher p-value than the term that was actually selected. Models containing such substitute terms may turn out to have qualities that make them useful, despite their not having been selected directly through the stepwise process. Model 12, one such model, is distinguished by having fewer terms than the Step 7 and Step 8 models, by having the highest AIC and BIC values of all of the models, and by lacking any high-emitter interaction terms. Without the high emitter interaction terms, Model 12 can be used for our purposes without having to estimate the proportion of NMHC emissions attributable to high emitting vehicles. On the other hand, the model is insensitive to any differences that may exist between normal and high emitters in the

way their NMHC emissions respond to fuel parameter changes–oxygen content changes in particular.[55] The coefficients of Model 12 are shown in Table 21.

Table 21. Estimated Coefficients for Model 12 for log NMHC (coefficients that were not statistically significant at the 0.05 level are indicated in bold)

Standardized Term	Model 12
Intercept	-1.6012
RVP	0.007973
T50	0.06046
T90	0.02133
AROM	0.008759
OLEF	-0.01457
OXYGEN	-0.01391
SULFUR	0.04696
HI-EMIT	1.7091
T90*T90	0.01633
T50*T50	0.02469
T90*OXY	0.01552
OXY*OXY	0.01288
T90*ARO	0.006814

c. Final Model Selection

Clearly, whatever model or models we select for NMHC must do a good job of predicting NMHC emissions as a function of all of the different fuel properties that are measured under

[55] While model 12 contains a high emitter term, that term affects only the intercept of the regression equation. This difference in intercept would be profoundly important if we were using the models to estimate expected emission inventories. In this case, though, we are interested in percent changes in emissions as a function of fuel parameter changes. By itself the high emitter term does not influence these changes in fuel effects.

California's program. By the most appropriate objective measures, all three of the models presented below in Table 22 perform that function. Indeed, their measures of predictive utility, as shown in the table, are so closely matched as to make use of those criteria for choosing one from among them seem arbitrary. Model 12 lacks any high-emitter interaction terms, a trait that makes it easier to use in the course of subsequent analyses. On the other hand, the fact that Model 12 does not distinguish high-emitters from normal emitters makes it insensitive to effects of that kind that the other two models capture, each in their own way (the Step-7 and Step-8 models each incorporate a different high-emitter interaction term, which are designated as "HI" in the table below).

Table 22. List of Candidate Models for NMHC Emissions

Model	No. of Terms	AIC	BIC	RMSE	Vehicle Error	Fuel Terms (In Addition to Linear Terms)
12	13	1507.7	1475.1	0.1227	0.4973	HI, T50*T50, T90*T90, T90*OXY, OXY*OXY, T90*ARO
Step-7	14	1507.6	1472.6	0.1227	0.4984	HI, T50*T50, T90*T90, T90*OXY, SUL*HI, OXY*OXY, T90*ARO
Step-8	15	1506.7	1471.7	0.1226	0.4982	**Step-7 Terms, T50*HI**

Thus we have decided to use the same approach to model selection for NMHC as we used with Tech 4 NOx emissions–to average the effects of the group of models that seem to be the best overall predictors. As can be seen from Table 23 the differences among these models are slight for normal emitters, but they differ a bit in their handling of the high-emitting vehicles. As discussed in the section on NOx modeling, this approach would not be workable for developing a compliance model, but can be used in the context of our evaluation of California's waiver request without its complexity being problematic. Use of the Step 7 and Step 8 models generates

separate effect estimates for normal and high emitters from each of the two models. For the Step 7 and Step 8 models, their normal emitter effects and their high emitter effects must be weighted by the estimated contributions to fleet reactive organic gasses (ROG) emissions attributable to normal and high emitters, respectively,[56] to obtain an overall predicted effect for each of these models. Model 12 requires no such weighting. Then these three model effects are averaged to obtain an estimated effect on NMHC emissions from adding 2 weight percent oxygen to gasoline. The result of these calculations for the fuel properties of the CEC-sponsored MathPro modeling effort is a -0.83 percent change in NMHC exhaust emissions.

Table 23. Exhaust NMHC Emission Change from Adding 2 Percent Oxygen to Fuel

Model	MathPro CEC Fuels/ Normal Emitters	MathPro CEC Fuels/ High Emitters	Other Properties at CA RFG3 Flat Limit Values
Step 7	-0.73%	-0.45%	-4.31%
Step 8	-0.76%	-1.80%	-4.49%
Model 12	-0.83%	-0.83%	-4.42%

While we have elected to develop our own models for evaluating exhaust NMHC emissions from Tech 4 vehicles, just as we did for NOx emissions, we have chosen not to do so for the Tech 3 and Tech 5 vehicles. The reasoning behind this decision for hydrocarbon modeling closely parallels the corresponding decisions made for our NOx model. Tech 3 vehicles' NMHC emissions will be a rapidly decreasing fraction of overall fleet exhaust

[56] CARB provided these estimates from the EMFAC7g model in an email message dated November 16, 2000. Specifically, 77 percent of 2005 ROG emissions from Tech 4 vehicles were attributed to "normal" emitters (< 2 times the HC standard), and 23% were attributed to "high" emitters (> 2 times the HC standard).

hydrocarbon emissions by 2005, and we are willing to rely upon California's PM3 modeling for these vehicles.[57] For Tech 5 vehicles, on the other hand, we are neither comfortable accepting the assumptions by which California arrived at effect estimates for these vehicles, nor do we have an adequate database to use in developing our own models. As discussed earlier in connection with decisions on NOx emissions, we believe that the superior fuel/air ratio control that is typical in Tech 5 vehicles will act to minimize the effects of oxygen changes on hydrocarbon emissions. Thus we believe the most reasonable assumption to make is that the Tech 5 vehicles' hydrocarbon emissions do not change at all with oxygen changes in the fuel in the range of zero to 2.0 percent by weight.

Granting or denying the waiver is also expected to affect non-exhaust VOC emissions through permeation and commingling. These issues are discussed in separate sections of this document. The VOC/oxygen relation for off-road vehicles is also addressed separately.

d. Integration of VOC/oxygen relation with refinery modeling results

As explained above, EPA selected three "preferred" exhaust NMHC models (Step 7, Step 8 and Model 12), and has chosen to average these model responses to estimate exhaust VOC effects in Tech 4 vehicles. The Step 7 and Step 8 models have property by high emitter

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[57] While CARB modeled total hydrocarbon (THC) for the Tech 3 vehicles, EPA modeled non-methane hydrocarbon for Tech 4 vehicles. For some purposes this difference would be problematic when trying to determine the effects of oxygen changes on the exhaust hydrocarbon emissions of the overall vehicle fleet. In this case the end product of our statistical modeling (that is actually used in subsequent analysis) is a percent difference in NMHC emissions that results when 2.0 Wt. percent of oxygen is removed from gasoline. Since oxygen seems to have, at most, a trivial effect upon Tech 3 vehicles' NMHC/THC ratios in the range of 0.0% to 2.7% oxygen (Pearson correlation coefficient = 0.165), we believe that the percent difference in THC when 2% oxygen is removed is an acceptable estimator of the corresponding percent difference in NMHC. In any case, the quantitative importance of whatever error might be introduced by this assumption is very low (Tech 3 vehicles are a minor part of the hydrocarbon emissions picture in 2005, and methane is a small fraction of total exhaust hydrocarbon emissions from Tech 3 vehicles).

interaction terms which predict that "normal emitters" and "high emitters" respond differently, on a percent change basis, when two fuel formulations are compared. In Section IV.C.3, we evaluated the NOx emission performance for twelve of the sixteen possible "waiver"/"no waiver" comparisons that we constructed from the cases which MathPro analyzed for EPA. Tables 24 and 25 below show the averaged "Waiver" to "No Waiver" NMHC percent changes for these same comparison scenarios, for "normal emitters" and "high emitters" respectively:

Table 24 Normal Emitter EPA Tech 4 Model "Waiver" to "No Waiver" NMHC Percent Changes

No Waiver Oxy level	Waiver Oxy level	Nationwide MTBE Use	Unocal Patent	Percent Change non-oxy to oxy (no waiver)	Percent Change oxy (waiver) to oxy (no waiver)
2.0	2.0	Reduced	Patent not avoided	-2.54	-1.28
2.7	2.7	Reduced	Patent not avoided	-2.58	-2.82
2.7	2.0	Reduced	Patent not avoided	-2.61	-1.35
2.0	2.0	Continues	Patent not avoided	-2.62	-0.38
2.7	2.7	Continues	Patent not avoided	-1.95	-1.13
2.7	2.0	Continues	Patent not avoided	-2.68	-0.44
2.0	2.0	Reduced	Patent avoided	-2.87	-0.81
2.7	2.7	Reduced	Patent avoided	-3.09	-1.53
2.7	2.0	Reduced	Patent avoided	-3.01	-0.95
2.0	2.0	Continues	Patent avoided	-3.10	-0.36
2.7	2.7	Continues	Patent avoided	-1.97	-1.62
2.7	2.0	Continues	Patent avoided	-3.24	-0.50

Table 25 High Emitter EPA Tech 4 Model "Waiver" to "No Waiver" NMHC Percent Changes

No Waiver Oxy level	Waiver Oxy level	Nationwide MTBE Use	Unocal Patent	Percent Change non-oxy to oxy (no waiver)	Percent Change oxy (waiver) to oxy (no waiver)
2.0	2.0	Reduced	Patent not avoided	-2.90	-1.01
2.7	2.7	Reduced	Patent not avoided	-2.87	-2.50
2.7	2.0	Reduced	Patent not avoided	-2.89	-1.00
2.0	2.0	Continues	Patent not avoided	-2.81	-0.35
2.7	2.7	Continues	Patent not avoided	-2.17	-1.03
2.7	2.0	Continues	Patent not avoided	-2.80	-0.34
2.0	2.0	Reduced	Patent avoided	-3.06	-0.78
2.7	2.7	Reduced	Patent avoided	-3.24	-1.37
2.7	2.0	Reduced	Patent avoided	-3.14	-0.86
2.0	2.0	Continues	Patent avoided	-3.37	-0.32
2.7	2.7	Continues	Patent avoided	-2.07	-1.49
2.7	2.0	Continues	Patent avoided	-3.44	-0.40

All of the percent change numbers in both tables are negative, indicating that these models predict better exhaust NMHC emissions for Tech 4 vehicles with an oxygen mandate than with a waiver. This is evident both in the differences between non-oxygenated "waiver" CaRFG3 and oxygenated "no waiver" CaRFG3, and in the differences between oxygenated "waiver" CaRFG3 and oxygenated "no waiver" CaRFG3. Comparison of corresponding columns between the tables shows that the differences in the normal and high emitter responses are not great.

We estimated Tech 3 exhaust VOC emission changes using the Tech 3 portion of the Phase 3 predictive model. Tech 3 non-oxygenated to "no waiver" oxygenated changes ranged from -5.83 percent to -2.40 percent. The "waiver" oxygenated to "no waiver" oxygenated changes ranged from -3.48 percent to -0.43 percent. We assumed no fuel-related exhaust VOC emission effects for the Tech 5 vehicles. This approach is the same used in our NOx analysis.

We estimated the exhaust reactive organic gas (ROG) emission changes resulting from the waiver for these various scenarios in a manner similar to our calculation of NOx emission changes. Since "normal emitters" and "high emitters" show slightly different percent change responses it was necessary to allocate the Tech 4 exhaust ROG emissions inventory to normal and high emitters. Based on previously cited information from CARB, we attributed 77 percent of 2005 ROG emissions to normal emitters and 23 percent to high emitters. [58] An example calculation is provided.[59]

The two sets of fuel properties which we selected from the CEC MathPro report to represent non-oxygenated and oxygenated CaRFG3 had (to the one decimal place precision

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[58] When we developed our models, we categorized high emitters based on average total exhaust HC emissions >0.82 grams per mile or average CO>6.8 grams per mile, twice the federal Tier 0 light duty vehicle standards. CARB was able to provide us with an estimate (23 percent), based on EMFAC7g, of the proportion of Tech 4 emissions from vehicles emitting at greater than twice the applicable standard for ROG, including vehicles certified to other than the federal standards. CARB also provided us with an estimate of the ROG emission proportion from vehicles exceeding twice the CO standard (10 percent), but could not provide an estimate of the total proportion of ROG emissions attributable to vehicles exceeding either or both of the standards. We elected to use 23 percent, rather than 33 percent (23+10) on the assumption that many of the vehicles exceeding twice the CO standard would also have exceeded twice the HC standard so that adding these two percentages would have double-counted these emissions. Since our analysis indicates that normal and high emitters generally respond similarly on a percent change basis, our conclusions are not substantially affected by the allocation assumptions.

[59] We used an estimate of 130.40 tons/day exhaust ROG to represent on-road gasoline vehicle South Coast emissions in 2005 without a waiver. We apportioned these emissions to the three Tech groups using factors from the PM3, and apportioned Tech 4 into normal and high emitters (16.6% for Tech 3, 41.6% for normal emitter Tech 4, 12.4% for high emitter Tech 4, and 29.4% for Tech 5). For the first scenario listed, “2.0,2.0, reduced, patent not avoided”, the Tech 4 normal emitter model “waiver “to “no waiver” responses shown are -2.54 and -1.28 percent, with equivalent “no waiver” to “waiver” changes of 2.61 and 1.30 percent. The non-oxygenated market share for this scenario is 65 percent. We estimated the Tech 4 normal emitter change in tons/day as +((130.4)(65/100)(2.61/100)+(130.4)(35/100)(1.30/100))(41.6/100)=1.17 tons/day.

reported) the same Reid Vapor Pressure (RVP)[60] with and without a waiver. Thus, using the CEC MathPro report we would expect that the as-blended evaporative emissions characteristics of CaRFG3 with and without a waiver would not differ significantly. (Permeation and commingling, which will be discussed later, would likely result in differences in non-exhaust VOC emissions with and without a waiver.) The EPA MathPro analysis consistently showed RVP differences between "no waiver" and "waiver" CaRFG3. Table 10 in section III.B.2 shows that in each case, the RVP of the ethanol-oxygenated "no waiver" CaRFG3 exceeded that of either the ethanol-oxygenated or non-oxygenated "waiver" CaRFG3. Therefore, based on this modeling we would expect that the as-blended evaporative VOC emissions would decrease if a waiver were granted.

We have estimated the emission effect associated with the as-blended RVP difference according to the following procedure. We used an equation derived from CARB's emission inventory model, MVEI7G, and which was published in a report prepared by Sierra Research for the American Methanol Institute. This equation related RVP to evaporative ROG emissions, in tons per day, for the on-road fleet in the South Coast Air Basin.[61] This equation is $y = 2.6243x^2 - 8.4856x + 6.2251$ for year 2005, where y is tons/day and x is RVP in pounds per square inch. Using this equation, we computed the percent changes in evaporative emissions for RVP changes between the "no waiver" and "waiver" fuels. We applied these percent change estimates

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60 RVP is a measurement of gasoline volatility. Evaporative emissions increase with increasing RVP.

61 Report No. SR00-0101 "Potential Evaporative Emission Impacts Associated with the Introduction of Ethanol-Gasoline Blends in California" January 11, 2000.

to our value for on-road evaporative ROG emissions in order to estimate the on-road evaporative emissions impact of the waiver. An example calculation is shown.[62]

We added the exhaust emission estimates to the evaporative emission estimates. These totals are shown in Table 26, with a negative number indicating a decrease in emissions with a waiver (i.e., additional reductions beyond those that would be achieved with CaRFG3 fuel without a waiver). Our estimates, combining exhaust and evaporative tons/day, indicate a net decrease in on-road ROG emissions would occur for each scenario evaluated, <u>if the only non-exhaust VOC effect was due to differences in as-blended RVP.</u>

[62] We used an estimate of 139.00 tons/day for South Coast on-road evaporative emissions. Using the "2.7,2.7,continues,patent avoided" scenario as an example, the RVPs for oxygenated "no waiver", non-oxygenated and oxygenated "waiver" CaRFG3 are 6.84, 6.60 and 6.73 psi. From the equation, we estimated a percent change in evaporative emissions of -9.06% for the 35% non-oxygenated share going from 6.84 to 6.60 psi, and a percent change of -4.20% for the 65% oxygenated share going from 6.84 to 6.73 psi. The net evaporative emissions change is (139)(35/100)(-9.06/100)+(139)(65/100)(-4.20/100)=-8.21 tons/day reduction. We are aware that the equation relating RVP to emissions in tons/day does not reconcile with our baseline inventory estimate. We believe that this is due, in part, to our inclusion of all on-road gasoline evaporative emissions sources provided in the inventory we were using (light duty vehicle, all categories of gasoline trucks and motorcycles). We are assuming that this equation will approximate the percent changes in evaporative emissions for all categories.

Table 26 Estimated South Coast On Road Exhaust+As-Blended Evaporative VOC Emission Inventory Changes With Waiver (tons/day)

No Waiver Oxy Level	Waiver Oxy Level	Nationwide MTBE Use	Unocal Patent	VOC
2.0	2.0	Reduced	Patent not avoided	-1.27
2.7	2.7	Reduced	Patent not avoided	-10.27
2.7	2.0	Reduced	Patent not avoided	-10.64
2.0	2.0	Continues	Patent not avoided	-1.85
2.7	2.7	Continues	Patent not avoided	-6.52
2.7	2.0	Continues	Patent not avoided	-11.23
2.0	2.0	Reduced	Patent avoided	-5.23
2.7	2.7	Reduced	Patent avoided	-7.89
2.7	2.0	Reduced	Patent avoided	-9.76
2.0	2.0	Continues	Patent avoided	-5.25
2.7	2.7	Continues	Patent avoided	-6.34
2.7	2.0	Continues	Patent avoided	-9.79

We have so far considered the changes in VOC emissions from non-oxygenated fuel associated with attendant changes in exhaust and "as-blended" evaporative VOC. There are two additional non-exhaust VOC emission effects which must be considered: the effect of ethanol on permeation and commingling. Specifically, CARB points out in its February 7, 2000 submittal that soft fuel components of automotive fuel systems tend to be more permeable to ethanol than to other hydrocarbons in gasoline. The commingling effect refers to the RVP increase (with resultant emission increase) that occurs when ethanol-oxygenated gasoline and other gasoline are mixed. EPA's consideration of permeation and commingling is discussed in subsequent sections of this document. Specifically, CARB points out in its February 7, 2000 submittal that soft fuel components of automotive fuel systems tend to be more permeable to ethanol than to other hydrocarbons in gasoline

CARB points out in its February 7, 2000 submittal that fuels that do not use ethanol achieve lower evaporative emissions because of the elimination of additional permeation losses that can occur with ethanol use. Thus, CARB asserts that the production of non-oxygenated fuel would cause a decrease in VOC emissions due to elimination of these additional permeation losses. The elimination would be due to displacement of RFG blends using ethanol by non-oxygenated RFG.

Increased VOC emissions would be expected to occur from RFG blends using ethanol due to increased evaporative emissions (of VOC from the entire gasoline blend) from fuel permeation of soft fuel system components. In its February 7, 2000 submittal, CARB estimates that the difference in evaporative emissions when comparing non-oxygenated gasoline to gasoline/ethanol blends with 2.0 weight percent oxygen is about 13 tons/day for all federal RFG areas due to permeation losses, assuming 100 percent penetration of non-oxygenated fuels. If we assume that permeation emissions are proportional to ethanol content, the difference in evaporative emissions between the displaced gasoline containing 2.7 weight percent oxygen and non-oxygenated gasoline is equivalent to approximately 17.5 tons/day decrease in VOC for all federal RFG areas, again assuming 100 percent penetration of non-oxygenated fuels. In certain of the scenarios we considered, if a waiver were granted gasoline oxygenated at 2.0 percent would displace gasoline oxygenated at 2.7 percent. We would expect that some reduction in permeation emissions would result from this change in the oxygen content of oxygenated CaRFG3. Assuming the same proportional relationship between oxygen content and permeation emissions, a reduction of about 4.5 tons/day would occur if the oxygen content of all CaRFG3 in federal areas were reduced from 2.7 percent to 2.0 percent. We adjusted the VOC decrease for

each of the scenarios that we examined, based on the penetration of non-oxygenated fuel for that particular scenario, and multiplying that amount by 0.6 to represent the change in the SCAQMD, since that region makes up approximately 60 percent of all RFG used in California. Table 27 below contains estimates, based on the above assumptions, of the reductions in permeation emissions that would occur under the various comparison scenarios.

Table 27 VOC Emission Reductions due to reductions of permeation losses with Waiver

					Permeation Emission Change (tons VOC /day)		
No Waiver oxy. wt. pct.	Waiver oxy. wt pct.	Nationwide MTBE Use	Unocal Patent	Non-oxy Penetration Pct.	Oxy no waiver to non oxy	Oxy no waiver to oxy waiver	Total
2.0	2.0	Reduced	Patent not avoided	65	-5.1	0.0	-5.1
2.7	2.7	Reduced	Patent not avoided	60	-6.3	0.0	-6.3
2.7	2.0	Reduced	Patent not avoided	65	-6.8	-0.9	-7.8
2.0	2.0	Continues	Patent not avoided	50	-3.9	0.0	-3.9
2.7	2.7	Continues	Patent not avoided	40	-4.2	0.0	-4.2
2.7	2.0	Continues	Patent not avoided	50	-5.3	-1.4	-6.6
2.0	2.0	Reduced	Patent avoided	74	-5.8	0.0	-5.8
2.7	2.7	Reduced	Patent avoided	54	-5.7	0.0	-5.7
2.7	2.0	Reduced	Patent avoided	74	-7.8	-0.7	-8.5
2.0	2.0	Continues	Patent avoided	50	-3.9	0.0	-3.9
2.7	2.7	Continues	Patent avoided	35	-3.7	0.0	-3.7
2.7	2.0	Continues	Patent avoided	50	-5.3	-1.4	-6.6

There is considerable uncertainty associated with estimation of permeation losses. Thus, these quantitative estimates should be viewed with caution. The insufficiency of information to estimate waiver-related permeation effects with a high degree of confidence is discussed below.

e. Confidence regarding permeation effects

This subsection provides additional data on permeation losses and associated VOC emissions. Fuel system permeation is well documented in the automotive industry. There are at least 17 papers published by the Society of Automotive Engineers (SAE) since 1990 that deal with the issue. Toyota recently presented the results of a study to CARB and EPA that concludes

that the switch from MTBE to ethanol in California gasoline will increase evaporative emissions due to permeation. CARB's predicted increases are based on conservative estimates of probable fuel system permeation sources, flexible fuel supply hoses, plastic fuel tanks, and fuel tank filler neck hoses in on-road vehicles. The vehicles are at rest, without the effects of increased temperatures and other conditions that could be expected to increase or add to permeation losses (i.e., permeation losses that occur independent of ethanol content). Typical vehicles were represented by two theoretical fuel system designs, fuel injected and carbureted, each using different hose materials and hose lengths that are approximations on current and older technology vehicles. Permeation estimates for the designs were based on representative types of hose material and the wetted surface areas. The permeation rates were provided by Dupont, a leading supplier of fuel system materials. The rates are from two Dupont studies published by the Society of Automotive Engineers (920163 and 970307). The fuel system configurations and the choice of permeation rates are reasonable approximations in the absence of detailed survey information to describe California's on-road fleet.[63]

CARB acknowledges the lack of sufficient vehicle information to allow satisfactory characterization of vehicles and their permeation potential but believes the approximations are directionally correct. We believe that the estimates are uncertain, but nonetheless useful for evaluating California's petition.[64]

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[63] Presentation by Brent Crary, Toyota Motor Corporation; "Effects of Ethanol on Emissions of Gasoline LDVs"; Ann Arbor, Michigan; May 4, 2000

[64] In our recent rulemaking for Tier 2 Motor Vehicle Emissions Standards (65 FR 6793, February 10, 2000) we recognized the potential for higher evaporative emissions due to fuel permeation when using ethanol blend gasolines and we included a requirement for emissions deterioration factors to be developed using fuels containing 10 volume percent ethanol or to demonstrate that alcohol-resistant, low permeability materials were used.

We agree that additional data are necessary to allow the emissions modeling that would support and quantify the ethanol permeation effect. CARB's Resolution 99-39 requires CARB to conduct research on permeation and calls for a progress report in October, 2000 (which has been completed) and a final report on the results of permeation testing by December, 2001. A contract is also planned that includes a literature search for the ethanol permeation rates of fuel system materials, collection of information regarding fuel system materials that will be in use in year 2003, distribution of vehicles in that year's fleet, and an estimate of the fleet-wide effect of permeation emissions. Until more data regarding these factors is developed, it is not possible to better characterize the permeation effect.

2. Commingling effect

When ethanol is mixed with gasoline, a non-linear increase in Reid Vapor Pressure (RVP) occurs. For example, if gasoline with an RVP of 8.0 psi is mixed with non-denatured ethanol (which alone has an RVP of 2.4 psi) in a 90 percent gasoline/10 percent ethanol mixture, the RVP of the resulting mixture is approximately 9.1 psi, a 1.1 psi RVP increase.[65] Because of this RVP boost associated with ethanol blending, a blendstock with a sufficiently low RVP must be used to achieve the desired RVP in the ethanol-blended gasoline. The initial amount of ethanol added to non-oxygenated gasoline results in greater incremental increases in RVP than subsequent amounts. This non-linear increase makes small amounts of ethanol very important to RVP.

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[65] SAE paper 940765, "In-Use Volatility Impact of Commingling Ethanol and Non-Ethanol Fuels" Peter J. Caffrey and Paul A. Machiele, US EPA.

An RVP boost will also occur when ethanol-blended gasoline is mixed with non-oxygenated or ether-oxygenated gasoline. For example, the RVP of a mixture containing equal volumes of a 7 psi ethanol-oxygenated RFG blend and a 7 psi non-oxygenated RFG blend would be greater than 7 psi. When an ethanol-oxygenated gasoline is mixed with an MTBE-oxygenated gasoline the resulting increase in RVP is somewhat smaller than it is when an ethanol-oxygenated gasoline is mixed with a non-oxygenated gasoline. Mixing of ethanol-oxygenated gasoline with other gasoline is called commingling and the associated RVP boost is called the commingling effect. Federal and California regulations prohibit or restrict commingling in the distribution system. These restrictions do not apply to commingling in vehicle fuel tanks, however. In the discussion that follows, commingling refers to the mixing of ethanol-gasoline with non-ethanol gasoline in vehicle fuel tanks.

The commingling effect is of concern because non-exhaust hydrocarbon emissions from vehicles increase with increasing RVP. Commingling has not been an issue within Federal RFG areas in California because there has been virtually no ethanol used in these areas.[66] With the requirement of 2.0 weight percent oxygen content in effect, the phase-out of MTBE in California could result in some commingling of ethanol and MTBE-oxygenated gasolines if MTBE and ethanol were both used during the phase-out period. Commingling would no longer be a significant issue once the phase-out of MTBE is complete, if all gasoline sold within federal RFG areas was then ethanol-oxygenated gasoline, as expected. (Some commingling within federal RFG areas could still occur in theory, however, when a vehicle is refueled both inside and outside of a federal RFG area; however, in California this is unlikely to involve a substantial

[66] RFG surveys, which collected samples from retail stations in Los Angeles, San Diego and Sacramento confirm this.

fraction of the gasoline). In the case of an oxygen waiver, however, ethanol-oxygenated and non-oxygenated RFG could share the market within federal RFG areas in California. In the waiver scenario, we would expect the incidence of commingling to be substantially higher than in the other scenarios described. Consequently, a waiver of the oxygen content requirements may cause an increase in non-exhaust HC emissions due to commingling.[67]

Although mixing of ethanol with gasoline produces a nominal 1.0 psi RVP boost over a wide range of ethanol blending volumes, the actual average RVP increase that will occur in a mixed ethanol/non-oxygenated market would be, under any foreseeable set of conditions, significantly less than 1.0 psi.[68] The effect of commingling on average RVP depends on a number of factors.

Various models estimate the commingling effect under differing input assumptions about the amount of ethanol used, base RVP of the fuels, and consumer refueling habits.[69] Perhaps the most important factors for predicting the commingling effect in an ethanol/non-oxygenated market are brand loyalty (i.e., to what extent consumers refuel with one brand, several brands or many brands of gasoline), and market share (i.e., the fraction of the gasoline sold in an area that contains ethanol). [70] Both the EPA model and D.M. Rocke's probability model indicate that

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67 This would be true either for a complete waiver of the oxygen requirements, or any partial waiver which includes removal of the per-gallon minimum oxygen requirement (1.5 weight percent), allowing some non-oxygenated CaRFG3 in federal areas.

68 The term "average RVP increase" refers to the actual increase in RVP caused by commingling in a subset of the entire gasoline pool, averaged over the entire gasoline pool.

69 Specifically, SAE paper 940765, cited earlier, describes a model developed by Caffrey and Machiele of EPA. Also, Dr. D.M. Rocke, University of California at Davis, developed a probability model ("UCD model") to study commingling. A description of the model developed by Dr. D. M. Rocke, University of California at Davis for CARB is available at http://www.arb.ca.gov/cbg/carfg3/Comming1.PDF . The computer code for the model is available at http://www.arb.ca.gov/cbg/carfg3/Comming.PDF .

70 With the assumption that a given brand will not sell both ethanol and non-ethanol gasoline in the same geographic area.

when "loyalty" is held constant, the commingling effect peaks at or near 50 percent ethanol market share. (For the EPA model the effect peaks at 30 to 50 percent market share, depending on the model parameters selected.) These models also show that as loyalty decreases at a constant market share, i.e. as consumer refueling choices become more random, the commingling effect increases.

Although these models may accurately predict the magnitude of the commingling effect for a given set of input conditions, the conditions that would be applicable to the Federal RFG areas in California if a waiver were granted are largely unknown. CARB staff has estimated the likely commingling effect to be about 0.1 psi in a ethanol/non-oxygenated market with an oxygen waiver in effect. (See Docket A-2000-10, Document II.D.18-b). The assumptions used in their analysis included ethanol in 100 percent of premium gasoline and 46 percent of regular gasoline. They further assumed no grade switching. Thus, they assumed that commingling could occur only in vehicles using regular gasoline. They assumed that regular gasoline made up 75 percent of the gasoline pool, with the remaining 25 percent premium. Additionally, they assumed that 63 percent of regular grade customers switch brands, potentially resulting in commingling. Using a "simplified" analysis they calculated the RVP boost for each possible outcome under two scenarios (three refills with initial tank volume at quarter tank level and 4 refills at half tank level) and averaged the results for each scenario. They estimated the RVP increase of the gasoline pool by multiplying the average result by the commingling probability (63 percent) and the regular grade market share (75 percent). Average increases (above 7 psi) were 0.12 psi for the 1/4 tank scenario and 0.16 psi for the half tank scenario. These calculations were based on ethanol content of 10 volume percent (about 3.5 weight percent oxygen) in

ethanol oxygenated gasoline. CARB determined, based on the UCD commingling model, that the boost with 5.7 volume percent ethanol content RFG (about 2.0 weight percent oxygen) would be about 80 percent of the boost with 10 volume percent. Consequently, they applied an 80 percent adjustment factor to their 10 volume percent RVP boost estimates to estimate the boost if 5.7 volume percent ethanol content oxygenated RFG were used. Resultant estimates were 0.10 psi average RVP increase for the quarter tank scenario and 0.13 psi for the half tank scenario.

The commingling effect under a waiver is difficult to forecast, depending on oxygenated/non-oxygenated market share, the oxygen content used in ethanol-oxygenated RFG, brand loyalty and other factors related to owner refueling behavior. Considering available information, however, we are concerned that CARB's 0.1 psi estimate of the commingling average RVP effect is likely to be low, even given many of CARB's underlying assumptions.

EPA (Caffrey and Machiele) developed a model to help assess the average in-vehicle RVP increases that could occur if ethanol-oxygenated gasoline were commingled with non-oxygenated (or MTBE-oxygenated) gasoline during vehicle refueling.[71] CARB's oxygenate use and grade split assumptions result in an overall oxygenated CaRFG3 share of about 60 percent. EPA's model using this 60% oxygenated market share, CARB's 7 psi RVP base and a loyalty curve (curve 2) which the model's authors felt "may be the best representation of customer brand loyalty available for this model" estimated an RVP increase of 0.24 psi. [72] This model

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[71] SAE paper 940765, "In-Use Volatility Impact of Commingling Ethanol and Non-Ethanol Fuels" Peter J. Caffrey and Paul A. Machiele, US EPA.

[72] See the SAE paper for discussion of loyalty curve data. For the EPA model runs relating to the waiver evaluation user-specified parameters selected were owners=1000, fills=100 (simulating 1000 owners refueling 100 times), loyalty curve= 2, fill curve=3, tank heel=0.1. The model was

assumes that ethanol content would be 10 volume percent. Applying the 80 percent adjustment factor used by CARB to estimate the RVP boost with 5.7 percent ethanol, the average RVP increase is 0.19 psi.

CARB also assumed that all premium gasoline would be ethanol-oxygenated so that commingling would occur only within regular grade gasoline. EPA's model, with the other parameters identical, but with the market share at 46 percent, CARB's regular grade assumption, estimated an average RVP increase of 0.28 psi. If the 80 percent factor is applied to adjust to 5.7 percent ethanol content, the expected average RVP increase for regular grade is 0.22 psi. Assuming that this applies to the 75 percent regular grade portion of the pool, the overall average RVP increase would be about 0.17 psi.

MathPro's refinery modeling for EPA estimated ethanol-oxygenated market shares between 26 percent and 65 percent for various waiver scenarios. For waiver scenarios where oxygen content was 2.0 weight percent, oxygenated market shares ranged from 26 percent to 50 percent. MathPro's refinery modeling also predicted an as-blended RVP of about 6.6 psi for oxygenated and non-oxygenated CaRFG3 in these 2.0 weight percent oxygen scenarios. EPA's commingling model, with a base RVP of 6.6 psi estimated an average RVP increase of 0.27 psi from commingling at 26 percent ethanol market share, and a 0.28 psi average RVP increase at 50 percent market share (with other model parameters as in previous runs.) Adjusting these estimates to 5.7 percent ethanol content using the 80 percent factor results in an average RVP increase of about 0.22 psi.

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run for a non-reformulated gasoline scenario in order to simulate commingling of non-oxygenated gasoline and ethanol-oxygenated gasoline rather than MTBE and ethanol gasolines.

If the overall market share of ethanol-oxygenated gasoline was 50 percent, and it was assumed, as CARB suggests, that ethanol was used in 100 percent of premium, the ethanol market share in regular grade (with a 25/75 premium/regular split) would be around 33 percent. EPA's model estimated an average RVP increase of 0.29 psi at 33 percent market share with the other parameters as above. Adjusting for 5.7 percent ethanol, and applying this increase to 75 percent of the gasoline pool results in an average RVP increase of about 0.17 psi. If the oxygenated market share was 26 percent and ethanol was used in 100 percent of premium, with CARB's assumptions, virtually no oxygen would be used in regular gasoline. Consequently, under these conditions the average RVP increase due to commingling could be negligible. CARB's commingling analysis considered a scenario where ethanol was used in 100 percent of premium and zero percent of regular, with the only commingling coming from a small amount of grade switching. CARB estimated a commingling effect under this scenario of around 0.02 psi. While it is possible that this scenario could occur, CARB's own evaluation of the commingling effect does not identify this as the likely commingling scenario.

EPA has also examined the Sierra Research report prepared for the American Methanol Institute. Sierra Research modified the EPA commingling model to allow variation of the ethanol content of ethanol-oxygenated gasoline and to allow different base RVPs for the ethanol-oxygenated and non-oxygenated portions of the gasoline pool. Sierra Research generated RVP boost curves as a function of ethanol market share for a scenario in which a 6.9 psi RVP ethanol blend was used in conjunction with a 6.5 psi RVP non-oxygenated fuel. Sierra Research estimated minimum, maximum and average commingling impacts at various market shares. EPA understands the minimum curve estimates the commingling impact when gasoline

containing 5.75 volume percent is used, the average curve with 7.8 percent and the maximum curve with 10 percent. The minimum curve peaks at around 0.2 psi and is fairly flat, with the RVP boost close to 0.2 psi for ethanol market shares between about 30 to 70 percent. This curve is at or above 0.1 psi between about 15 and 90 percent market share. EPA has not validated the modifications to the model. Additionally, MathPro's refinery modeling does not indicate that there will be a substantial difference in RVP between ethanol-oxygenated and non-oxygenated CaRFG3 in a shared market. However, Sierra's analysis does conclude that the commingling effect, if ethanol is used at 5.7 volume percent, is likely to be around 0.2 psi over wide range of market shares.

We believe, in the absence of better information that it is at least, if not more, reasonable to assume for waiver evaluation that the commingling effect would be around an average RVP increase of 0.2 psi rather than 0.1 psi. CARB estimated the commingling effect by calculating a small number of refueling iterations under a set of assumptions that would tend to produce an RVP boost estimate at the lower end of the range of likely RVP increases (i.e., 100 percent ethanol use in premium gasoline, no grade switching, and ethanol content at 5.7 volume percent). Furthermore, EPA's analysis indicates that even with these assumptions concerning ethanol use, content and grade switching, the commingling effect is still likely to be about 0.17 psi which is closer to 0.2 psi than 0.1 psi. Also, if any of CARB's assumptions do not strictly hold, the commingling effect is likely to increase above this estimate.

EPA acknowledges that the octane characteristics of ethanol may result in preferential use in premium gasoline, that many owners do not switch grades, and that RFG suppliers may well elect to use ethanol at 5.7 volume percent. There are, however, to our knowledge no hard data to

support CARB's assumptions with respect to ethanol use in 100 percent of premium gasoline and the total absence of grade switching. EPA's model also shows that the magnitude of the commingling effect increases as brand loyalty decreases. Under "no loyalty" conditions, the model predicts commingling effects of up to about 0.4 psi. Adjusting this result with the 80 percent factor shows that a commingling effect in excess of 0.3 psi could occur when ethanol is used at 5.7 volume percent. While a "no loyalty" assumption is extreme and is not likely to approximate owner behavior, this result shows that there is a potential for the commingling effect to exceed 0.2 psi. Since commingling is very sensitive to variables such as brand loyalty which have been only crudely estimated, a plausible case can be made for commingling effects ranging from an average RVP increase of 0.1 to 0.3 psi.

In order to offset the effect of commingling, the CaRFG3 regulations contain a 0.1 psi reduction from Phase 2 in the RVP flat limit (from 7.0 to 6.9 psi). This 6.9 psi flat limit is applicable to refiners electing to use the predictive model evaporative compliance option. It appears, based on available information, that most, if not all, refiners are likely to utilize the evaporative compliance option with or without a waiver. Thus, the absence or presence of a waiver is unlikely to result in a difference in the utilization of this option. Moreover, CARB is committed by resolution and state law, to conduct additional evaluations of the commingling effect. Through Resolution 99-39, CARB is required to evaluate the real-world emissions impact of commingling in 2003 and beyond, and report its findings and recommendations to the Board by December 2001. CARB will investigate the expected prevalence of ethanol and non-oxygenated CaRFG3 by supplier, grade and geographic area. CARB will also collect information on refueling patterns, brand and grade loyalty as well as samples of actual in-use

fuels. California state law (Senate Bill 989) requires that CaRFG3 maintain or improve upon emissions and air quality benefits achieved by California Phase 2 RFG in California as of January 1, 1999. Therefore, if CaRFG3's more stringent RVP limit does not offset the commingling effect, this law would require CARB to take additional measures to assure there would be no real-world increase in HC emissions. There is some uncertainty about the mitigative measures that California can and will apply if the magnitude of the commingling effect exceeds CARB's expectations. CARB would first have to assess the magnitude of the commingling effect, and then determine what can be done to offset this effect. It does not appear that California would be required by state law or resolution to take any action unless it determined that the commingling effect exceeds the 0.1 psi that was anticipated. Thus, any mitigative action would likely only serve to maintain the equivalent of the 0.1 psi waiver to no waiver differential.

CARB intends to conduct a field study to evaluate the expected real world emissions impact of commingling CaRFG3 containing ethanol with CaRFG3 not containing ethanol. However, according to the draft protocol for CARB's commingling study, (as modified March 31, 2001; see Docket A-2000-10, Document Number II-D-81) we anticipate that the study will be conducted at retail gasoline facilities in northern California that are currently marketing non-MTBE gasoline. Thus, even if the CARB commingling study accurately evaluates commingling effects within the study area, it is somewhat uncertain that these results will be applicable to the South Coast Air Quality Management District. The magnitude of the commingling effect is highly sensitive to brand loyalty, which conceivably could differ significantly from area to area. The magnitude of the RVP boost is mitigated somewhat by the presence of MTBE. A

commingling study done prior to the elimination of MTBE could potentially underestimate the effects of commingling on RVP. The focus of EPA's waiver analysis has been to estimate the emissions effect of the waiver in the SCAQMD after MTBE has been phased out. Potentially, CARB could conclude from a field study that the commingling impact is sufficiently addressed, when in fact it is not in the area and time of concern.

It is also not clear whether the 0.1 psi RVP adjustment adopted by CARB should be treated, for purposes of evaluating California's waiver request, as offsetting the VOC emissions associated with commingling. The 0.1 psi reduction in RVP applies regardless of whether a waiver is granted, hence the emissions benefit of the reduction occurs whether or not a waiver is granted while the commingling emissions occur only if a waiver is granted. Consequently, EPA estimated the effect of commingling RVP increases on VOC emissions for each of the twelve scenarios considered, assuming commingling RVP increases of 0.1 and 0.2 psi.[73]

EPA used the equation from the Sierra Research report, cited earlier, to estimate the percent increase in evaporative VOC emissions that could be expected relative to the "as-blended" state for each scenario and each level of commingling RVP increase. We then applied these percent change factors to our estimates of the "as-blended" evaporative VOC emissions inventory to estimate the increase in evaporative tons/day associated with each scenario.[74] Table

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[73] For purposes of this decision EPA does not need to decide whether it is appropriate to offset the expected increase in emissions from commingling with the 0.1 psi RVP reduction adopted by CARB. This is because even if the 0.1 psi offset is applied, as discussed below, VOC reductions are too uncertain to resolve what effect of a waiver would have on ozone.

[74] Again, using the "2.7,2.7,continues,patent avoided" scenario as an example, we calculated an 8.21 ton/day VOC decrease due to the "as-blended" RVP difference, resulting in an "as-blended" waiver evaporative VOC inventory of 130.79 tons/day (139.0-8.21). The average RVP, based on the MathPro RVP and marketshare estimates, is 6.68 psi (6.60x35%+6.73x65%). Using the Sierra Research equation, we estimated a 4.02 percent increase (69.449/66.763-1) in evaporative VOCs with a 0.1 psi boost to 6.78 psi. Applying this to the "as-blended" evaporative inventory yields an estimate of 5.26 tons/day (130.79x4.02%) increase in evaporative emissions from on-road vehicles if the commingling effect is 0.1 psi.

28 below gives our estimates of commingling VOC increases attributable to on-road vehicles assuming various levels of RVP increase due to commingling.

Table 28 Estimated South Coast On Road Commingling VOC Increases With Waiver (tons/day)

No Waiver Oxy Level	Waiver Oxy Level	Nationwide MTBE Use	Unocal Patent	VOC 0.1psi boost	VOC 0.2 psi boost
2.0	2.0	Reduced	Patent not avoided	5.55	11.22
2.7	2.7	Reduced	Patent not avoided	5.15	10.41
2.7	2.0	Reduced	Patent not avoided	5.15	10.41
2.0	2.0	Continues	Patent not avoided	5.55	11.22
2.7	2.7	Continues	Patent not avoided	5.25	10.61
2.7	2.0	Continues	Patent not avoided	5.15	10.41
2.0	2.0	Reduced	Patent avoided	5.38	10.87
2.7	2.7	Reduced	Patent avoided	5.22	10.54
2.7	2.0	Reduced	Patent avoided	5.17	10.45
2.0	2.0	Continues	Patent avoided	5.39	10.89
2.7	2.7	Continues	Patent avoided	5.26	10.63
2.7	2.0	Continues	Patent avoided	5.18	10.47

3. CO effect of decreasing oxygen

Removing oxygen from gasoline will tend to increase emissions of CO for the on-road vehicle fleet. CARB in its February 7, 2000 submission has estimated the expected CO emissions from representative non-oxygenated gasoline, as well as gasoline containing 2.0 weight percent oxygen, both of which would meet the CaRFG3 standards. CARB estimates that reducing gasoline oxygen content from 2.0 weight percent to zero would result in an estimated increase of 4.6 percent in CO. This CARB-estimated increase does not take into account mitigative effects claimed by CARB of reducing the sulfur content from 20 ppm to 10 ppm and reducing T50 from 211° F to 205° F to offset the increase in exhaust VOC. According to

CARB's February 7, 2000 submission, (available in Docket A-2000-10, or at http://www.arb.ca.gov/cbg/Oxy/wav/oxywav.htm) the net result of removing oxygen from California gasoline would be an increase in CO of about 2.7 percent (95 tons per day divided by 4,995 tons per day). (CARB felt that reduction of sulfur and T50 were necessary in order for the non-oxygenated fuel to meet the CaRFG3 regulations.)

We used CARB's assumptions regarding oxygen effect on CO (as detailed in Appendix G of its staff report for the CaRFG3 rule) in calculating CO increases.[75] For conservatism, we did not adjust the CO increases for sulfur or T50 reductions.[76] We split the CO increase among the Tech 3, Tech 4 and Tech 5 categories as CARB did, assuming that there would be no change in CO as a result of oxygen reduction in Tech 5 vehicles (which CARB assumed as well).[77]

In our assessment of a waiver's effect on CO we included the effect, where applicable, of reduced oxygen content in oxygenated CaRFG3 (i.e., 2.0 percent versus 2.7 percent oxygen by weight) . Table 29 below summarizes our estimates of the on-road CO increases expected under various scenarios (in tons per day).

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75 More specifically, we used the percent CO reductions per weight percent increase in oxygen reported in Appendix G, Table 4 of CARB's staff report on CaRFG3. (Appendix G available at: http://www.arb.ca.gov/regact/carfg3/appg.pdf). These factors were converted to percent CO increases per weight percent reduction in oxygen to calculate increases due to oxygen removal. CARB did report CO increases per weight percent oxygen reduced in other tables in the appendix. These factors differ slightly.

76 Reductions in T50 and sulfur may result in lower CO emissions. However, we are uncertain of the basis for the quantitative estimates of these effects contained in Appendix G of the CARB staff report, and cannot provide alternative estimates. (Appendix G available at: http://www.arb.ca.gov/regact/carfg3/appg.pdf). We also note that comparison of certain MathPro modeling cases indicates that sulfur may be higher in non-oxygenated CaRFG3 than oxygenated CRFG3.

77 Separate reductions were reported for MY86-90 and MY91-95. We combined these into a single factor to represent Tech 4 vehicles using statewide tons per day estimates contained in Table 3, Appendix G of CARB's staff report on CaRFG3, as weights. (Appendix G available at: http://www.arb.ca.gov/regact/carfg3/appg.pdf). The factors expressed as CO percent changes per percent increase in oxygen, and parenthetically as changes per percent decrease in oxygen are -5.07% (5.34%) for Tech 3, and -3.16% (3.26%) for Tech 4. We used 2414 tons/day CO to represent on-road gasoline vehicle South Coast emissions in 2005 without a waiver. We allocated 14.2% to Tech3, 44.3% to Tech4, and 41.5% to Tech5, based on Appendix G, Table 3.

Table 29: Estimated South Coast On Road CO Emission Inventory Changes With Waiver

No Waiver Oxy Level (wt. %)	Waiver Oxy Level	Nationwide MTBE Use	Unocal Patent	CO increase (tons/day)
2.0	2.0	Reduced	Patent not avoided	71.96
2.7	2.7	Reduced	Patent not avoided	92.37
2.7	2.0	Reduced	Patent not avoided	112.93
2.0	2.0	Continues	Patent not avoided	55.35
2.7	2.7	Continues	Patent not avoided	61.58
2.7	2.0	Continues	Patent not avoided	95.36
2.0	2.0	Reduced	Patent avoided	81.92
2.7	2.7	Reduced	Patent avoided	83.13
2.7	2.0	Reduced	Patent avoided	123.48
2.0	2.0	Continues	Patent avoided	55.35
2.7	2.7	Continues	Patent avoided	53.88
2.7	2.0	Continues	Patent avoided	95.36

Oxygen removal is also likely to increase CO emissions from off-road vehicles. EPA's estimate of off-road oxygen effects is discussed in detail in Section III.C.4. below.

4. Off-road vehicles and engines

Changes in fuel formulation are expected to affect emissions of off-road vehicles and engines (off-road sources) as well as on-road vehicles. Directionally, a decrease in fuel oxygen, all else constant, would be expected to increase exhaust HC and CO emissions and decrease NOx emissions for both off-road sources and on-road vehicles. Emission models such as CARB's predictive model and EPA's Complex Model, however, were based solely on emissions test data from on-road vehicles. These models may not accurately quantify the response of off-road sources to changes in fuel properties, because of substantial differences in engine and emission control technology between the two categories. There is no comparable fuel effects model for

off-road sources nor are there extensive test data available to characterize fuel effects on off-road source emissions.

CARB staff used the Tech 3 portion of the predictive model, which represents older on-road vehicles, as a tool to estimate exhaust emission effects from off-road sources. CARB noted in their February 7, 2000 letter that the Tech 3 model may represent the exhaust emissions effect from larger four-stroke off-road sources reasonably well. CARB recognized that the model's usefulness may be very limited in predicting emissions effects for smaller engines and in two-stroke engines responsible for the majority of reactive organic gas emissions from off-road sources.

We share CARB's concern about the limited ability of the predictive model to represent off-road source emissions. The Tech 3 portion of the predictive model is intended to be representative of older closed-loop three-way catalyst vehicles. This technology is not representative of the current off-road source fleet.

As an alternative, we have used information in an EPA document, Report No. NR-003, to estimate the changes in the exhaust emissions from off-road sources that would result if a waiver were granted.[78] This report concluded that the fuel effects on exhaust VOC, NOx and CO emissions for off-road sources are mainly due to changes in oxygen content. The report estimated emission effects (in percent change in emissions per percent of fuel oxygen added) for four-stroke engines based on tests of 13 engines. These effects were -4.5% for HC, +11.5 percent for NOx and -6.3 percent for CO. The report estimated emission effects for two-stroke

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[78] "Exhaust Emission Effects of Fuel Sulfur and Oxygen on Gasoline Nonroad Engines", Report No. NR-003, November 24, 1997, Christian E. Lindhjem, U.S. EPA

engines as -0.6 percent for HC, +18.6 percent NOx, and -6.5 percent for CO based on tests of one engine.

We combined the four-stroke and two-stroke effects into a single set of effects by weighting them according to statewide two-stroke and four-stroke emission fractions of ROG, NOx and CO calculated from emission inventories for 2005.[79] The weighted percent changes per percent increase in oxygen are -2.25 percent for HC, +12.62 percent for NOx and -6.33 percent for CO.

RVP is expected to be the fuel property most influential in determining evaporative emissions from off-road sources. MathPro's modeling for EPA shows that the as-blended RVP of CaRFG3 is likely to decrease with an oxygen waiver. We have assumed the same percentage emissions decreases for evaporative emissions from off-road sources and on-road vehicles . We realize that some evaporative emission increases due to commingling could potentially occur in off-road as well as on-road vehicles and engines. In our analysis we assumed the same range of possible RVP increases and applied the same percent change factors and calculation method used to evaluate commingling emission increases in on-road vehicles. We have not attempted to quantify any permeation emission changes associated with off-road sources.

We have estimated the likely off-road source emissions impacts of a waiver on NOx, ROG and CO for the comparison scenarios that we have included in our on-road analysis. Given the assumptions discussed above, it is obvious that off-road NOx is predicted to decrease, while CO and exhaust ROG emissions are predicted to increase with a waiver under all scenarios (since oxygen decreases). Evaporative ROG emissions are predicted to decrease with a waiver under

[79] See analysis in memo to docket (in A-2000-10, Document Number II-B-1)

all scenarios (since as-blended RVP decreases). Our estimates of the impact of the waiver on off-road emissions should be considered with some caution. Clearly, the small amount of engine test data and simplified analysis used to develop estimates of oxygen effects on off-road emissions are not comparable to the large body of data and sophisticated analysis used to estimate fuel property emissions effects in on-road vehicles. Furthermore, we were unable to obtain inventory information which explicitly identified the gasoline portion of South Coast off-road emissions, and needed to make certain assumptions to derive these estimates.[80]

We have added these off-road source estimates to the on-road estimates for each of the scenarios to produce a total estimate of emission effects. These total estimates include exhaust and evaporative emission effects, including commingling and permeation. We realize that there is considerable uncertainty associated with our estimate of the effect of a waiver on off-road sources. We believe, however, that we have made a reasonable effort to quantify these emissions, and to consider whether the inclusion of the emission estimates of off-road sources changes the conclusions that we would reach based on analysis of on-road impacts only. The off-road estimates are shown below in Table 30 and the total estimates are summarized in Table 31 in Section III.D.

[80] Our 2005 no-waiver baseline off-road inventory estimates in tons/day were NOx=25.51, exhaust ROG=95.39, evaporative ROG=25.18, and CO=1073.84. See analysis in memo to Docket A-2000-10, Document Number II-B-1.

Table 30: Estimated South Coast Off Road Emission Inventory Changes With Waiver

				Emission Inventory Changes (tons/day)				
No Waiver Oxy Level	**Waiver Oxy Level**	**Nationwide MTBE Use**	**Unocal Patent**	**NOx**	**VOC no comm.**	**VOC 0.1 psi boost**	**VOC 0.2 psi boost**	**CO**
2.0	2.0	Reduced	Patent not avoided	-3.34	2.32	3.33	4.35	101.18
2.7	2.7	Reduced	Patent not avoided	-3.89	1.33	2.26	3.22	132.82
2.7	2.0	Reduced	Patent not avoided	-4.94	2.17	3.10	4.06	161.31
2.0	2.0	Continues	Patent not avoided	-2.57	1.65	2.66	3.68	77.83
2.7	2.7	Continues	Patent not avoided	-2.59	1.00	1.95	2.92	88.55
2.7	2.0	Continues	Patent not avoided	-4.28	1.48	2.41	3.37	135.58
2.0	2.0	Reduced	Patent avoided	-3.80	1.96	2.93	3.93	115.18
2.7	2.7	Reduced	Patent avoided	-3.50	1.44	2.39	3.35	119.54
2.7	2.0	Reduced	Patent avoided	-5.34	2.68	3.62	4.57	176.75
2.0	2.0	Continues	Patent avoided	-2.57	0.98	1.96	2.95	77.83
2.7	2.7	Continues	Patent avoided	-2.27	0.67	1.62	2.60	77.48
2.7	2.0	Continues	Patent avoided	-4.28	1.66	2.60	3.56	135.58

D. Effect of total emission changes

The changes in NOx, VOC, and CO inventories are based upon refinery modeling predictions of the most economic levels of oxygen use for both a waiver and non-waiver scenario considering various possible developments regarding nationwide MTBE use and the Unocal patent (as discussed in Section III.A.2). Table 31 below summarizes the effect of a waiver on NOx and VOC and CO inventories for twelve of sixteen possible "no waiver"/"waiver" comparison scenarios which can be constructed from MathPro's modeling for EPA. Table 31 incorporates consideration of all exhaust and evaporative emission changes from on-road vehicles (including commingling and permeation), as well as changes in off-road source emissions.

In Table 31 the columns for VOC emissions reflect the estimated impact of a waiver on actual VOC emissions (in tons/day), considering exhaust and evaporative emissions, including commingling and permeation, from on-road and non-road vehicles. The columns differ based on the estimates of average increase in RVP associated with commingling. For example, "VOC 0.1 psi boost" would reflect the impact of a waiver on the VOC inventory if commingling increases the average RVP by 0.2 psi, but this increase is treated as partially offset by CARB's adoption of a 0.1 psi reduction in RVP.[81] The column "VOC no boost" would reflect the impact on the VOC inventory if commingling increases RVP by 0.1 psi, and this increase is treated as fully offset by CARB's adoption of a 0.1 psi reduction.

[81] This column would also reflect the impact of a waiver on the VOC inventory if commingling increases the average RVP of the gasoline by 0.1 psi and the impact is not offset.

Table 31: Waiver Impacts at Various Commingling-Related RVP Boosts

				Waiver Case Oxygen Market Shares and Oxy Levels			Emission Inventory Changes (tons/day) (On-road, off-road and all exhaust and evaporative VOC such as permeation and commingling)				
No Waiver Oxy Level	Waiver Oxy Level	Nationwide MTBE Use	Unocal Patent	% Oxyfuel	% Non-Oxyfuel	Year-round Oxygen Avg	NOx	VOC no boost[82]	VOC 0.1 psi boost[83]	VOC 0.2 psi boost[84]	CO
2.0	2.0	Reduced	Patent not avoided	35	65	1.0	-6.60	-4.02	2.54	9.23	173.13
2.7	2.7	Reduced	Patent not avoided	40	60	1.5	-7.53	-15.24	-9.15	-2.94	225.19
2.7	2.0	Reduced	Patent not avoided	35	65	1.0	-9.61	-16.23	-10.14	-3.93	274.24
2.0	2.0	Continues	Patent not avoided	50	50	1.3	-5.08	-4.10	2.46	9.15	133.18
2.7	2.7	Continues	Patent not avoided	60	40	1.9	-4.68	-9.72	-3.51	2.81	150.12
2.7	2.0	Continues	Patent not avoided	50	50	1.3	-8.21	-16.35	-10.26	-4.05	230.93
2.0	2.0	Reduced	Patent avoided	26	74	0.9	-7.20	-9.05	-2.69	3.79	197.11
2.7	2.7	Reduced	Patent avoided	46	54	1.6	-7.08	-12.12	-5.96	0.33	202.67
2.7	2.0	Reduced	Patent avoided	26	74	0.9	-10.89	-15.55	-9.44	-3.20	300.23
2.0	2.0	Continues	Patent avoided	50	50	1.3	-4.84	-8.17	-1.80	4.69	133.18
2.7	2.7	Continues	Patent avoided	65	35	2.0	-4.78	-9.35	-3.13	3.20	131.36

[82] This scenario is equivalent to a 0.1 psi RVP boost from commingling completely offset by California's 0.1 psi adjustment to its standards. For purposes of this decision EPA does not need to decide whether it is appropriate to offset the expected increase in emissions from commingling with the 0.1 psi RVP reduction adopted by CARB, as even if the 0.1 psi offset is applied , as discussed in III.D., VOC reductions are too uncertain to resolve what effect a waiver would have on ozone.

[83] Equivalent to a 0.2 psi RVP boost from commingling offset by California's 0.1 psi adjustment to its standards resulting in a net commingling effect of 0.1 psi.

[84] Equivalent to a 0.3 psi RVP boost from commingling offset by California's 0.1 psi adjustment to its standards resulting in a net commingling effect of 0.2 psi.

2.7	2.0	Continues	Patent avoided	50	50	1.3	-8.73	-14.73	-8.61	-2.36	230.93

Table 31 shows that there would be a net NOx decrease and CO increase with the waiver under all scenarios. It also shows a VOC increase with the waiver for two of the twelve scenarios at 0.1 psi commingling average RVP increase and for seven scenarios at 0.2 psi commingling increase. This table also includes an estimate of a "Year-round Oxygen Average".[85]

Table 32 summarizes the individual components of the VOC change associated with the waiver. This table illustrates that the impact of a waiver on VOC emissions is considerably more complex to model than the impact of a waiver on either NOx or CO emissions. Thus, there is significant uncertainty as to the overall VOC effect of a waiver–in both the amount and the direction of the effect.

[85] This average was estimated considering likely oxygenate usage patterns during the winter season in the absence of a mandate. For purposes of this analysis, year-round oxygen averages for the waiver cases are calculated based upon the summertime market share and oxygen levels modeled in the MathPro report and assume wintertime oxygenated gasoline use patterns in San Diego and Sacramento to be the same as summertime use patterns and wintertime oxygen use in Los Angeles to be at 2.0 weight percent in all gasoline as required under the state's wintertime oxygenated gasoline program. In fact, there is reason to believe that these wintertime oxygen use patterns would be the most likely wintertime use patterns to emerge in a waiver scenario. MathPro has concluded this in its analysis for EPA.

Table 32: Components of Total VOC Change [86]

No Waiver Oxy Level	Waiver Oxy Level	Nationwide MTBE Use	Unocal Patent	On-Road VOC Changes					Non-Road VOC Changes			
				Exhaust	As-Blended Evap	0.1psi Comminglin g	0.2 psi Comminglin g	Permeation	Exhaust	As-Blended Evap	0.1psi Comminglin g	0.2 psi Commingling
2.0	2.0	Reduced	Patent not avoided	2.05	-3.32	5.55	11.22	-5.1	2.92	-0.60	1.01	2.03
2.7	2.7	Reduced	Patent not avoided	2.81	-13.08	5.15	10.41	-6.3	3.70	-2.37	0.94	1.89
2.7	2.0	Reduced	Patent not avoided	2.44	-13.08	5.15	10.41	-7.8	4.54	-2.37	0.94	1.89
2.0	2.0	Continues	Patent not avoided	1.47	-3.32	5.55	11.22	-3.9	2.25	-0.60	1.01	2.03
2.7	2.7	Continues	Patent not avoided	1.58	-8.10	5.25	10.61	-4.2	2.47	-1.47	0.96	1.92
2.7	2.0	Continues	Patent not avoided	1.85	-13.08	5.15	10.41	-6.6	3.85	-2.37	0.94	1.89
2.0	2.0	Reduced	Patent avoided	2.33	-7.56	5.38	10.87	-5.8	3.33	-1.37	0.98	1.97
2.7	2.7	Reduced	Patent avoided	2.56	-10.45	5.22	10.54	-5.7	3.33	-1.89	0.94	1.91
2.7	2.0	Reduced	Patent avoided	2.83	-12.59	5.17	10.45	-8.5	4.96	-2.28	0.94	1.90
2.0	2.0	Continues	Patent avoided	1.78	-7.03	5.39	10.89	-3.9	2.25	-1.27	0.98	1.97
2.7	2.7	Continues	Patent avoided	1.86	-8.21	5.26	10.63	-3.7	2.16	-1.49	0.96	1.92
2.7	2.0	Continues	Patent avoided	2.28	-12.08	5.18	10.47	-6.6	3.85	-2.19	0.94	1.90

[86] The sum of these components, in some cases, differ trivially from the totals shown in the previous table due to rounding.

In its February 7, 2000 submission CARB asserts that ozone impacts from increases in CO emissions (because of the decrease in oxygen in gasoline) would be offset by the corresponding VOC decreases. CARB argued that the accompanying decrease in VOC emissions (because of the reduction of permeation losses associated with diminished use of ethanol) would serve to offset these CO increases. While California's petition included an analysis generally intended to support this conclusion, that analysis relied heavily upon relative reactivity factors (developed by Dr. Carter of the University of California, Riverside).[87] Even using the relative reactivity approach that California employs, it is not at all clear that the changes in CO and VOC that occur with a waiver of the oxygen content requirement would be neutral with respect to ozone. Specifically, our examination of 12 scenarios shows that 2 of the scenarios result in a VOC increase even at 0.1 psi commingling effect, and therefore no offset of CO emissions. The 10 remaining scenarios each show a VOC decrease; however, 30 to 50 percent of these scenarios show VOC decreases that would be inadequate (using California's relative reactivity factors) to offset the CO increase.[88] Consequently, at the very least, there is a significant question regarding whether the combination of VOC and CO emission changes

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87 In the past, the Agency has not relied upon the use of such relative reactivity factors for evaluating the impact of emissions on ozone formation [see 63 FR 48792 and 65 FR 42924].

88 CARB used reactivity factors of 2.21 g ozone/g VOC (representing evaporative VOC emissions) and 0.065 ozone/g CO, as developed by Dr. Carter. Since reductions in VOC are associated with evaporative emissions (i.e., reduced RVP of non-oxygenated fuel as predicted by MathPro, and decreased permeation losses due to reduced use of ethanol), the reactivity factor associated with evaporative VOC is more representative than a weighted reactivity factor representing exhaust and evaporative VOC. Using the reactivity factor for evaporative VOC results in a relationship of one ton of VOC equivalent to 32 tons of CO; that is for each 32 ton increase in CO, a one ton reduction in VOC would provide an offset in terms of ozone neutrality in terms of the Carter reactivity factors. Using a weighted reactivity of 50 percent exhaust and 50 percent evaporative emissions results in a reactivity factor of 2.6 g ozone/g VOC, and a relationship of one ton of VOC equivalent to 40 tons of CO. Using the factor of 2..6 g ozone/g VOC results in 30 percent of the scenarios in which there are VOC decreases failing to offset the CO increases; using 2.1 g ozone/gVOC results in 50 percent failure.

associated with a waiver would have a neutral or even a detrimental impact on ozone even using California's relative reactivity approach. Based on all the evidence before the Agency, it is reasonable to believe that if a waiver were granted to California, there would be an expected reduction in NOx, an increase in CO, and significant uncertainty about the overall change in VOCs. The evidence is not clear what impact the emissions changes from a waiver would have on ozone and does not clearly show whether a waiver would reduce, not affect, or even increase ozone..

All three of the pollutants discussed above influence ozone formation. The atmospheric chemistry is complex, but directionally we would expect NOx reductions to reduce ozone formation, CO increases to contribute to ozone formation, and VOC emissions to either increase or reduce ozone, depending on whether VOC emissions increase or decrease. In order to determine the direction of the overall impact on ozone from the changes in these three pollutants, we must consider the expected change in each of them and the overall balance that results from the directionally different impacts on ozone.

EPA does not believe that the evidence provided by California and developed through its own analyses clearly demonstrates what effect a waiver would have on ozone. This is because: 1) there are three pollutants whose emission rates would be altered by a waiver, and all three affect ozone formation, 2) these pollutants are not equivalent, on a ton-for-ton basis, in their effects on ozone formation, and 3) while NOx will decrease with a waiver, CO is expected to go up and VOC may go up or down resulting in an uncertain impact on ozone.

EPA has carefully evaluated all of the information in front of it, including information submitted by CARB, other interested parties, and developed by EPA. After considering what effect a waiver might have on the properties of California reformulated gasoline, and the effect

this change in fuel properties would have on emissions from highway and off-road sources, EPA concludes that there has been no clear demonstration as to what effect a waiver would have on ozone. There is significant uncertainty associated with determining the expected emissions impact of a waiver, largely based on uncertainty regarding the expected impact on VOCs produced when gasoline containing ethanol is mixed with other gasolines in the marketplace. As a result, there is significant uncertainty in balancing the emissions impacts of the three different pollutants involved, each of which affect ozone, and determining their overall effect on ozone. This uncertainty has not been resolved, even using the approach suggested by CARB.[89]

[89] We need not discuss the technical issues associated with an expected reduction in NOx and any associated reduction in PM.

APPENDIX A. What is EPA's statutory authority under 211(k)(2)(b)?

For purposes of California's waiver request, EPA interprets section 211(k)(2)(B) as follows. The key question before the agency involves the air quality impacts of a waiver for the relevant NAAQS. EPA believes it should not make a determination of interference or prevention and should not grant a waiver unless the impacts of a waiver are clearly demonstrated for each applicable NAAQS. Absent such a clear demonstration, EPA is not able to determine whether a waiver would aid, hinder, or have no effect on attainment of a NAAQS. It is important that the impacts of a waiver be clearly demonstrated for each applicable NAAQS, because EPA believes it should not grant a waiver unless, at a minimum, it has been clearly demonstrated that granting a waiver would aid in attaining at least one NAAQS, and would not hinder attainment for any other NAAQS. Once this minimum threshold has been met, EPA would have the authority to grant a waiver if the degree of impact were considered to interfere or prevent attainment. While EPA need not determine in this case what degree of impact is necessary to prevent or interfere with the NAAQS, EPA would have significant discretion in making such a determination. Even once EPA determines that this minimum threshold is met, EPA has the discretion to consider factors other than impact on the NAAQS in determining whether to exercise its discretion to grant a waiver. The following analysis explains the basis for using this interpretation in acting on California's waiver request.

A. Section 211(k)(2)(B) Generally

Clean Air Act section 211(k)(2)(B), 42 U.S.C. § 7545(k)(2)(B), requires that reformulated gasoline contain at least 2.0 percent oxygen by weight. This statutory provision also allows EPA to waive the oxygen content standard under certain circumstances. Section 211(k)(2)(B) states:

> The oxygen content of the gasoline shall equal or exceed 2.0 percent by weight (subject to a testing tolerance established by the Administrator) except as otherwise required by this Act. The Administrator may waive, in whole or in part, the application of this subparagraph for any ozone nonattainment area upon a determination by the Administrator that compliance with such requirement would prevent or interfere with attainment by the area of a national primary ambient air quality standard.

Thus, the RFG regulations must contain a 2.0 percent oxygen content requirement,[90] unless the agency makes a determination that compliance with this requirement will prevent or interfere with an area's ability to meet a primary NAAQS.[91] If EPA makes such a determination, EPA may reduce or eliminate the oxygen content requirement for gasoline sold in that area. EPA may consider waiving the oxygen requirement either in response to a request from an outside party or at the agency's own initiative. Moreover, because the statute directs EPA to waive the oxygen requirement "in whole or in part" upon making the necessary determination, it would appear that Congress intended for EPA to determine, where reasonably possible, how much of a

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90 EPA's regulations allow for compliance with a 2.0 percent per gallon oxygen standard, as well as a 2.1 percent average oxygen standard (refiner by refiner), with a per gallon minimum of 1.5 percent oxygen by weight.

91 EPA also may waive the oxygen content standard, pursuant to section 211(k)(2)(A), if it causes NOx emissions to increase above baseline levels.

waiver is appropriate in connection with each individual waiver request. It is reasonable to assume that Congress intended for EPA to limit a waiver to no more than that reasonably necessary to address any identified interference.

Because the statute does not define the terms "prevent or interfere," EPA may interpret these ambiguous terms in a reasonable manner that is consistent with the statutory language and Congressional intent. Additionally, because the Act uses both the terms "prevent" and "interfere," we may reasonably conclude that the terms do not have identical meanings. Moreover, it would be reasonable for EPA to interpret the term "prevent" as referring to some effect that is more serious than "interference." While prevention could be reasonably understood as an effect that stands as an absolute or practical barrier to achieving attainment, interference could be understood as an effect that makes achieving the NAAQS more difficult, but that does not itself necessarily prevent attainment. Therefore, the determination necessary to waive the oxygen content standard based on interference depends on the level of increased difficulty required and the circumstances under which such effects will constitute interference for purposes of the statutory provision.

In determining what kinds of information and factual considerations are relevant for grating a waiver of the oxygen content standard, and the minimum level of certainty required, it is instructive to look at several sources of guidance, including the structure and language of section 211; the legislative history of the 1990 amendments to the Clean Air Act; and the use and meaning of the term "interference" and similar terms elsewhere in the Act. Because we find that California has failed to meet the minimum threshold for demonstrating interference, it is unnecessary for us to separately evaluate whether California has demonstrated that the oxygen requirement "prevents" attainment.

B. Interpreting interference with attainment

Congress included the oxygen content requirement in the Clean Air Act Amendments of 1990 to serve particular Congressional objectives.[92] Congress also included the waiver provision in section 211(k)(2)(B), which identifies the considerations that Congress thought important enough to potentially outweigh the objectives of the oxygen content requirement. Determining where to strike the balance between these competing interests is at the heart of interpreting and implementing the oxygen waiver provision.

1. The statutory text

a. Section 211(k)

The reformulated gasoline program provides air emission benefits that help nonattainment areas achieve improvements in air quality. The centerpiece of section 211(k) is the requirement for EPA to promulgate regulations requiring the greatest reduction in emissions of VOCs and toxic air pollutants achievable through the reformulation of conventional gasoline. Accordingly, the performance standards under section 211(k)(3)(B) require certain minimum reductions in VOC and air toxics from all federal RFG, and EPA can and has required additional reductions under paragraph (k)(1).[93] Paragraph (2) of section 211(k) establishes a number of

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92 Congressional objectives for the oxygen requirement included environmental considerations, as well as a desire to support domestic agriculture and to enhance national energy security. *See, e.g.*, 136 CONG. REC. S3504, S3522 (1990), *reprinted in* COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS, 103RD CONG., 4 A LEGISLATIVE HISTORY OF THE CLEAN AIR ACT AMENDMENTS OF 1990, at 6836 (1993) [Hereinafter "Legis. Hist."]. ("this amendment . . . will reduce toxic aromatics currently used to boost octane in gasoline; it will reduce ozone-forming automobile emissions; it will begin to reduce our dependance on imported oil; and it will enhance rural and farm economies.") (Comments of Senator Conrad).

93 Section (k)(3) directs the agency to require compliance with the more stringent of either an RFG formula or an RFG performance standard. EPA determined that the performance standard was the more stringent. See, Standards for Reformulated and Conventional Gasoline, 59 Fed. Reg. 7716, 7722 (Feb. 16, 1994). Section (k)(1) provides EPA with the general authority to require the greatest emission reductions achievable considering certain other factors such as cost and other environmental impacts.

general content requirements applicable to federal RFG. These include, in addition to the oxygen content requirement, a cap on NOx emissions from RFG,[94] a limitation on benzene content, and a ban on heavy metals (such as lead or manganese).

Because one of the primary objectives of the RFG program is to help areas achieve the NAAQS for ozone by requiring reductions in VOC emissions, clearly EPA may consider the impact of the oxygen content requirement on VOC emissions when evaluating waivers under section 211(k)(2)(B). The impact of the oxygen requirement on NOx and CO emission is also a relevant consideration for waivers decision.[95]

The limitation on increases in NOx emissions in 211(k)(2)(A) includes the following language:

> If the Administrator determines that compliance with the limitation on emission of oxides of nitrogen . . . is technically infeasible, considering the other requirements applicable under this subsection to such gasoline, the Administrator may, as appropriate to ensure compliance with this subparagraph [regarding NOx emissions], adjust (or waive entirely), any other requirements of this paragraph (including the oxygen content requirement . . .).

Thus, to the extent that the Administrator determines that the oxygen content requirement makes it technically infeasible to reformulate gasoline without causing increases in NOx emissions compared to baseline gasoline, the Administrator may waive the applicability of the

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[94] While 211(k)(2)(A) prohibits NOx emissions from RFG that are greater than such emissions from baseline gasoline, EPA exercised its general authority under 211(c)(1) to require reductions in NOx emission from Phase II RFG of 6.8%.

[95] NOx and CO emissions may contribute to concentrations of ground level ozone, and NOx emissions may also contribute to PM.

oxygen requirement. This provision creates a relatively bright-line test, indicating that where it is technically infeasible to comply with both requirements, compliance with the NOx limitation is more important than compliance with the oxygen content requirement.

The broader waiver provision in (k)(2)(B) demonstrates a Congressional intent to address the potential impact of oxygen content on emissions from gasoline, including NOx, even where that impact does not make compliance with the NOx cap infeasible. Thus, Congress did not intend for the agency to implement the oxygen content requirement with a disregard for the impact that compliance with the standard would have on actual NOx and other emissions from gasoline. Where compliance with the oxygen content requirement would interfere with an area's ability to achieve the NAAQS, it is evident that Congress intended for EPA to have the discretion to determine that the oxygen content standard should give way.

It was reasonable for Congress to include both provisions, and it is reasonable to conclude that Congress intended for both provisions to address, among other things, the potential impact of oxygen content on NOx emissions. Accordingly, the language of 211(k)(2)(A) would provide EPA with a mechanism for avoiding NOx increases resulting from oxygen content, compared to baseline gasoline, without requiring a potentially difficult determination of interference with attainment of the NAAQS. Thus, the section 211(k)(2)(A) waiver provision would simply preserve the integrity of the statutory NOx limitation where that limitation is incompatible with any of the other provisions of 211(k)(2), including the oxygen content requirement. The waiver provision in 211(k)(2)(B), on the other hand, would allow EPA to waive the oxygen requirement whenever EPA found that there was sufficient evidence to conclude that a waiver would result in real-world changes in NOx and/or other emissions, such that without a waiver compliance with the oxygen requirement would have an adverse impact on

attainment of the NAAQS — whether or not such impact would make compliance with the section 211(k)(2)(A) NOx limitation technically infeasible. Considering section 211(k) as a whole, this is a reasonable interpretation of the interaction between these two waiver provisions.

Consequently, while the statute is ambiguous as to the meaning of "prevent or interfere", Congress did not clearly intend for section 211(k)(2)(A) to be the only mechanism for EPA to waive the oxygen content requirement based on NOx emission impacts. EPA may appropriately consider the impact of compliance with the oxygen content requirement on NOx emissions when evaluating waivers under section 211(k)(2)(B) as well.

b. Section 211(m)(3).

The oxygenated fuels program, section 211(m), requires gasoline in certain CO nonattainment areas to contain not less than 2.7 percent oxygen by weight during the portion of the year in which the area is prone to high ambient concentrations of carbon monoxide (i.e., during the winter). This section of the Act also includes an oxygen waiver provision that is similar to the section 211(k)(2)(B) waiver language.[96] Section 211(m)(3) reads:

> The Administrator shall waive, in whole or in part, the requirements of paragraph (2) [for 2.7 percent oxygen] upon a demonstration by the State to the satisfaction of the Administrator that the use of oxygenated gasoline would prevent or interfere with the attainment by the area of a national primary ambient air quality standard (or a State

[96] While EPA has received waiver requests under this section of the Act, EPA has not expressly interpreted this waiver provision. Notices were published in the Federal Register for both California and Utah on April 23, 1993, and June 10, 1993, respectively, announcing that these States had requested partial waivers of the 2.7 percent oxygen content requirement. Both States argued that the higher oxygen requirement would result in increased NOx emissions. EPA approved California's SIP with an oxygen content requirement lower than 2.7, but did not expressly interpret the 211(m)(3) waiver provision.

or local ambient air quality standard) for any air pollutant other than carbon monoxide.

This language clearly supports the view that a primary objective of the fuel program in section 211(k) of the Act is to provide air emission benefits to help ozone nonattainment areas get closer to attainment of the NAAQS, and it is consistent with the idea that where compliance with the oxygen content requirement is demonstrably inconsistent with attaining the ozone NAAQS (or another primary NAAQS) EPA has discretion to determine that the provisions requiring oxygen should yield.

c. Section 211(c)

The statutory preemption provisions of section 211, and EPA's interpretation of these provisions, may provide some guidance regarding an appropriate interpretation of the term "interfere" under section 211(k)(2)(B). Section 211(c)(4)(A) prohibits states from prescribing or enforcing controls respecting those characteristics or components of fuels or fuel additives for which the EPA has prescribed controls, unless EPA determines that the state control "is necessary to achieve" the NAAQS. CAA § 211(c)(4)(C). The Act indicates that EPA may make such a finding if "no other measures that would bring about timely attainment exist, or if other measures exist and are technically possible to implement, but are unreasonable or impracticable." Id. The criteria for waiving preemption — "necessary to achieve the NAAQS" — could be reasonably interpreted as more stringent than the criteria for waiving the RFG oxygen content requirement — "interfere with the attainment" of the NAAQS. That is, it would be reasonable for EPA to conclude that the oxygen content standard could *interfere* with attainment without a

waiver being *necessary* to achieve attainment, as EPA has interpreted this term for purposes of section 211(c)(4)(C).

As discussed above, EPA may reasonably interpret "interference" as referring to something less profound that "prevention." In turn, EPA could interpret the phrase "necessary to achieve," as defined in section 211(c)(4), as falling somewhere between prevention and interference. Accordingly, EPA's implementation of section 211(c)(4)(C) may provide some guidance regarding an appropriate interpretation of section 211(k)(2)(B). Agency precedent under section 211(c)(4)(C) is discussed in section 3 below.

As with these other section 211 provisions, the focus in section 211(k)(2)(B) is on the air quality impact of changes in fuel composition. In particular, section 211(k)(2)(B) is concerned with the impact of such changes on attainment of the NAAQS. Therefore, it is important to consider all of the pollutants that could reasonable be expected to affecting such attainment, including but not limited to NOx.

2. Legislative history

During consideration of the 1990 Clean Air Act Amendments, members of both the House and Senate expressed concerns about the impact of oxygen on emissions of air pollutants from gasoline, particularly NOx emissions. For example, Senator Durenberger made the following statements, in reference to section 211(k)(2)(A), during Senate Debate on the Conference Report:

> Both aromatics and oxygenates may increase NOX remissions (sic). The general theory of this reformulated gasoline program is that aromatics will be decreased and oxygenates will be added with offsetting impacts of NOX emission. Blended

> properly this theory can be implemented in practice without any increase in NOX emissions. However, if it turns out to be technically infeasible, the administrator (sic) is given authority to adjust the oxygen requirement. [Legis. Hist. at 853]

These statements support the conclusion that the section (k)(2)(A) waiver was intended to provide a test for waiving the other requirements of (k)(2) if any of these requirements turned out to be incompatible with the NOx cap, without the need for any demonstration regarding impact on attainment. The oxygen waiver provisions of section (k)(2)(B), however, was intended to serve a different purpose. The (k)(2)(B) waiver was intended to allow EPA to waive the oxygen content requirement in a broader range of circumstances, but with a potentially more complicated factual demonstration. EPA may waive the oxygen requirement, but only where such requirement turns out to be demonstrably at odds with attainment of a NAAQS.

Senator Dole commented, during Senate debate on the Daschle-Dole amendment, on an earlier version of a waiver provision that was very much like section 211(k)(2)(B): "Others have charged that we have so limited the definition of reformulated gasoline that the fuel may be environmentally damaging. However, we have included a waiver for the limitations if the administrator of EPA determines a fuel made under these broad specifications do lead to environmental damage." [Legis. Hist. at 6835]. This statement is significant for two reasons. First, it can be reasonably interpreted to suggest that Congress intended for the section (k)(2)(B) waiver provision to be generally available to address potential adverse impacts from oxygen content, including NOx emissions impacts. Second, it can be reasonably viewed as consistent with the idea that, when making a waiver determination, EPA should assess whether a waiver of the oxygen content requirement is likely to result in *real-world* emission reductions, so that EPA

can determine to what extent "environmental damage" would occur without a waiver. Presumably, such an assessment would, at least, include a comparison of the overall emissions performance of gasoline in an area with and without the oxygen content requirement in place.

Other statements in the legislative history acknowledge some ambiguity in the language of the statute, and suggest that Congress wanted EPA to closely scrutinize waiver requests. For example, during the Senate Debate on the conference report Senator Simpson urged EPA not to interpret the waiver provision too loosely: "EPA should also avoid a proliferation of too many different oxygen levels when it grants partial oxygen content waivers, to solve NOX cap or NAAQS problems under other provisions of section 211(k)." [Legis. Hist. at 1170]. Similarly the Conference Report indicated that "waiver of the oxygen requirements by petition must be the exception rather than the rule." [Legis. Hist. at 1024] The Report further suggested that an appropriate interpretation of the provision would require an area to "demonstrate that they are trying to comply with [the oxygen content] provision within their capabilities." [Legis. Hist. at 1024]. Collectively, in light of the legislative history, is reasonable for EPA to interpret these statements in the legislative history to suggest that EPA should grant waivers of the oxygen content requirement only where there is clear evidence that the oxygen requirement would interfere with attainment of a NAAQS.

Overall, while the legislative history does not resolve every ambiguity in the statutory text, it does suggest that Congress did not intend for the waiver provision to be overly permissive. That is, it is reasonable for EPA to require that the determination of prevention or interference with the NAAQS involve, at least, a meaningful evaluation of the real-world emissions effects of compliance with the oxygen content requirement in the relevant nonattainment area(s). Moreover, it is reasonable for EPA to require that this evaluation provide

a clear demonstration of what these real world emission effects are, in order to determine whether they make it more difficult for the area to attain the NAAQS.

In addition, the focus on promoting air quality in both the text of the statute and in the legislative history support the view that the required evaluation should clearly demonstrate the impact of a waiver on all relevant NAAQS, and that a waiver should not be granted where it may be reasonably anticipated to adversely impact an area's attainment of any NAAQS.

3. Agency Precedent

Prior to California's April 12, 1999 petition, EPA had not received a request for waiver of the oxygen content requirement under section 211(k)(2)(B). Therefore, EPA has not previously interpreted this statutory provision. However, other parts of the CAA use terms substantively similar to "prevent or interfere" in the context of different provisions, and EPA's interpretation of such terms is instructive for determining when interference has occurred for purposes of section 211(k)(2)(B).

a. Fuel control preemption waivers

Section 211(c)(4)(C) of the Act provides that before a State may prescribe controls respecting fuels or fuel additives it must demonstrate that such controls are "necessary to achieve" the NAAQS.[97] We discuss the possible relationship between the language "necessary to achieve" attainment and "prevent or interfere" with attainment in section 1.c. above.

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[97] California is excluded from this statutory preemption by CAA § 211(c)(4)(B).

In implementing section 211(c)(4)(C) EPA has established a criteria for demonstrating "necessity" that requires a State to (1) identify the quantity of emission reductions needed to achieve the NAAQS; (2) identify all other possible control measures and the quantity of reductions each would achieve; (3) explain in detail, with adequate factual support, which of those identified control measures are considered unreasonable or impracticable; and (4) show that even with implementation of all reasonable and practicable control measures, the additional emissions from the proposed fuel control are needed to meet the NAAQS in a timely manner.[98] See Approval and Promulgation of Air Quality Implementation Plans; Pennsylvania; Gasoline Volatility Requirements for the Pittsburgh-Beaver Valley Ozone Nonattainment Area, June 8, 1998 (63 Fed. Reg. 31116).[99]

EPA's implementation of the section 211(c)(4)(C) preemption waiver supports an interpretation of section 211(K)(2)(B) which would require a state to clearly demonstrate what effect a waiver would have on all relevant emissions. Thus, an oxygen content waiver must be supported by specific information that is sufficient to make the necessary findings. Such information, would include an evaluation of the likely composition of gasoline in the area (with and without the oxygen content requirement in place), and the impact of gasoline composition on relevant emission inventories. This evaluation must clearly demonstrate to what extent a waiver of the oxygen requirement would reduce or increase the level of emissions of some relevant pollutant, or pollutants (such as VOC, NOx, or CO). Additionally, this information should

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98 EPA may make a finding of necessity without an approved attainment demonstration so long as the state includes specific information sufficient to make the statutory showing that the proposed measure is necessary to meet the applicable NAAQS. See Approval and Promulgation of State Implementation Plans; Arizona—Maricopa County Ozone Nonattainment Area, June 11, 1997 (62 Fed. Reg. 31734, 31736).

99 EPA's August 1997 guidance document, Guidance on Use of Opt-In to RFG and Low RVP Requirements in Ozone SIPS, provides additional discussion of preemption waivers under CAA § 211(c)(4)(C).

clearly demonstrate the effect that any emission changes might have on attainment of a NAAQS, and clearly demonstrate that any such changes would have an overall benefit for purposes of attaining at least one NAAQS and not have an adverse impact on any other NAAQS. Therefore, for example, if removal of the oxygen content requirement in an area would result in fuel composition changes that affect the emissions of several pollutants, EPA should evaluate the overall effect of these emission changes on the NAAQS in that area.

b. SIP revisions.

In the context of revisions to state implementation plans EPA has interpreted NAAQS *non-interference*. For example, in Navistar International Trans. Co. v. EPA, 941 F.2d 1339 (6th Cir. 1991) the court affirmed EPA's denial of a proposed revision to Ohio's SIP based in part on EPA's conclusion that the State had failed to demonstrate that the revision would not interfere with timely attainment and maintenance of the NAAQS.

Navistar, a truck manufacturer, petitioned for review of EPA's denial of a proposed revision to the Ohio SIP. The Ohio Environmental Protection Agency (OEPA) submitted the proposed revision to EPA in March, 1986. On September 13, 1989 EPA issued a final rule disapproving Ohio's proposed revision.[100] The revision would have provided a variance for Navistar, granting Navistar extensions and relaxations of SIP requirements for several coating lines.[101] In order to approve the SIP revision, the Act required EPA to determine that the SIP provided for the timely attainment and subsequent maintenance of ambient air quality standards.

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100 EPA's decisions on the Ohio SIP and the proposed revisions for Navistar's were based on the provisions of Clean Air Act prior to the 1990 amendments; therefore, the Court reviewed Navistar's petition according to the law in effect at the time of EPA's final decision.

101 This would have allowed Navistar to operate several coating lines without meeting the VOC limitations identified in the SIP as representing implementation of reasonably available control technology (RACT).

See section 110(a)(2) (prior to the 1990 amendments). In such cases "the logical inquiry for the EPA is to assess whether the proposed change interferes with attainment." Navistar, 941 F.2d at 1342 (quoting United States Steel Corp. v. EPA, 633 F.2d 671, 674 (3d Cir. 1980).

Ohio's 1979 SIP demonstrated attainment by the end of 1982. Therefore, any revision to the SIP was required to demonstrate that the State would continue to achieve attainment on the same schedule, despite any relaxation of its provisions. In a technical support document prepared by EPA in connection with its decision on the Navistar SIP revision, EPA observed that a demonstration of non-interference "would generally be done by comparing the margin for attainment predicted by the approved ozone attainment demonstration and the increased emissions that would result under the proposed [revision]." Id. at 1348. Therefore, so long as the attainment demonstration would still show attainment on the same schedule, EPA could approve a SIP revision even where such revision might result in increases in some emissions. However, if the SIP revision would create a shortfall (an increase in emissions resulting in the attainment demonstration no longer showing attainment on the same schedule) the revision could not be approved – no matter how small that increase happened to be. Thus, any increment of emissions contributing to nonattainment would be considered interference for purposes of that provision.

Additionally, EPA stated that if there were reasons to believe that a substantial change in the emissions inventory had occurred since the attainment demonstration was prepared (that might change the margin of attainment) a revised demonstration would be necessary to support a SIP revision. In fact, the proposed revision for Navistar was based on an attainment demonstration prepared by the State in 1979, the adequacy of which was brought into question by the fact that measured violations of the ozone NAAQS had been detected in 1983 and 1984

(after the 1982 attainment date). Based on these violations the EPA argued, among other things, that the 1979 attainment demonstration could not be relied upon for purposes of showing non-interference, and that any revision to the SIP would require a revised attainment demonstration in order to document that the proposed changes would not interfere with timely attainment and maintenance. See Navistar, 941 F.2d at 1347. Thus, EPA interpreted non-interference as requiring that there be *no increment* of emissions increase above the limit necessary to demonstrate attainment. EPA also declined to make a determination of non-interference where there was a question about whether the available evidence accurately reflected the conditions within the State, and whether it clearly demonstrated that there would be no interference with attainment.

EPA's interpretation of non-interference in the context of SIP revisions supports our interpretation of interference under section 211(k)(2)(B). Particularly, this precedent supports the view that EPA has significant discretion to determine what level of impact on air quality may constitute interference. This precedent also supports our interpretation of section 211(k)(2)(B) as allowing EPA to require a reasonably thorough analysis regarding the likely composition of gasoline (with and without the oxygen content requirement in place) and the impact that any changes in gasoline composition would have on emissions. Further, this precedent supports the view that EPA may require a clear demonstration of the overall impact of a waiver on the relevant emissions inventories in an area, and a clear demonstration of the effect of such emission changes on attainment of each relevant NAAQS. The legislative history (discussed above) also supports this interpretation of the Act.

C. Policy Considerations

Because waiver of the oxygen content requirement is discretionary ― that is, EPA "may", but is not obligated to, waive the oxygen requirement if the statutory criteria are met ― EPA has significant discretion to consider additional factors.[102] So long as EPA's exercise of its discretion in this regard is not arbitrary, such considerations may appropriately serve as factors in such discretionary decision-making, where they reasonably promote the underlying Congressional objectives. *See Chevron, USA v. NRDC*, 467 U.S. 837 (1984). Because we find that California's petition for waiver of the oxygen content standard fails to meet the minimum requirements necessary for granting such waivers, we need not determine at this time each technical and policy consideration that might be relevant for determining whether to grant or deny such waivers in the future.

D. Conclusion

In light of the above considerations, we interpret the standard for granting an oxygen content waiver under section 211(k)(2)(B) to require, at least, a clear demonstration of what impact a waiver would have on all relevant emissions in an area, and a clear demonstration that the changes in emissions resulting from a waiver would have a beneficial impact for purposes of attaining at least one NAAQS, and would not hinder attainment for any other NAAQS.

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[102] For example, even where a state has successfully demonstrated that 2.0 percent oxygen in RFG interferes with attainment of the NAAQS by an area, it might be reasonable for EPA to deny a waiver request based on competing air-quality or non-air quality considerations.