STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION
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Arthur J. Rocque, Jr.
Commissioner

September 29, 2004

Jeff Holmstead, Assistant Administrator
Office of Air and Radiation
U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Dear ~~Mr. Holmstead~~ Jeff:

This correspondence supplements Governor Rowland's letter of April 22, 2002 regarding Connecticut's request for a waiver of the oxygenate requirement under the Clean Air Act (CAA). Pursuant to the authority provided in Section 211(k)(2)(B) of the CAA, the State of Connecticut now formally requests a waiver of the federal reformulated gasoline (RFG) program's requirement that fuels contain a minimum of 2 percent oxygen by weight.

The Connecticut Department of Environmental Protection is committed to environmental policies based on sound science, that protect Connecticut's citizens from air and water pollution in the most cost-effective manner. The oxygen requirement now in effect is inconsistent with all of these principles. The attached addendum to this request updates our technical record with the most current information available in support of our request. Most notably, a recent report entitled *Fuel Permeation From Automotive Systems*[1] released last week by the California Air Resources Board that documents emission increases in vehicles when ethanol replaced Methyl Tertiary-Butyl Ether (MTBE) in gasoline. The technical record compiled by the states of California and New York demonstrates that ethanol contributes to increases in emissions of Volatile Organic Compounds (VOCs) which hinders state's abilities to attain the National Ambient Air Quality Standards (NAAQS). Connecticut urges EPA to grant this waiver request to aid the State in attaining the NAAQs for both one-hour and eight-hour ozone.

No state should be forced to choose between clean air and clean water or between public health and environmental protection. It is simply not possible to protect air quality, water quality and Connecticut consumers absent relief from the oxygen mandate. I appreciate your consideration of our request and I urge U.S. EPA to act promptly on this request so that we can begin to realize the environmental benefits that a waiver will provide as soon as possible.

Sincerely,

Arthur J. Rocque, Jr
Commissioner

AJR:TB:tb

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[1] "Fuel Permeation From Automotive Systems", Final Report, September 2004

Addendum Number 1
Connecticut's Oxygen Waiver Request
September 2004

On January 1, 2004 Connecticut implemented a statutory ban on the use of Methyl Tertiary-Butyl Ether (MTBE) in gasoline. The ban was the culmination of a five-year effort to take the necessary measures to protect the State's groundwater resources from further MTBE contamination. As a result of this ban, Connecticut's gasoline is now blended with 10% ethanol to meet the oxygenate requirement. Consistent with the findings by the states of New York and California, we have also concluded that a minimum oxygen content is unnecessary and detrimental to our efforts to comply with the National Ambient Air Quality Standards (NAAQS). The technical record in support of this conclusion is considerable. The oxygenate requirement inhibits flexibility for fuel refiners and has prevented the development of a consistent, clean regional gasoline for the northeast. Pursuant to the authority provided in Section 211(k)(2)(B) of the Clean Air Act (CAA), the State of Connecticut now formally requests a waiver of the federal reformulated gasoline (RFG) program's requirement that fuels contain a minimum of 2 percent oxygen by weight.

On June 27, 2002 the Attorneys General for the States of Connecticut, Maine, Massachusetts, New Hampshire and New York filed an Amicus Curiae brief supporting a reversal of EPA's denial of California's waiver request. Considerable technical materials have been compiled by the State of California since Connecticut's waiver submission in April 2002. Most notably, a recent report by the California Air Resources Board concluding that evaporative emissions from automobile fuel systems increase when ethanol is used to replace MTBE in gasoline.[2] In addition to this report, the findings by the states of New York and California, we have also concluded that minimum oxygen content is not needed and, in fact, is detrimental to our clean air efforts at an increased expense.[3] In March of this year EPA approved an air toxics baseline adjustment for one refiner under 40 CFR 80.915 (g). Since then EPA has received additional requests for adjustments that EPA is in the process of approving. While EPA has been willing to provide refiners with additional flexibility in areas such as air toxics, EPA to date has not been willing to afford the necessary flexibility to States in their efforts to achieve compliance with the NAAQS. EPA's decision making in this area has been inconsistent and without a clear rationale.

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[2] "Fuel Permeation From Automotive Systems", Final Report, September 2004

[3] "Demonstration that the U.S. Environmental Protection Agency Must Grant California A Waiver From the Federal Reformulated Gasoline Oxygenate Mandate on Remand From the U. S. Court of Appeals For the Ninth Circuit", December 2003
"Background Information on Federal RFG Oxygenate Impacts on Particulate Matter", Revised September 19, 2003
"Evaporative Emissions From Offroad Equipment", June 21, 2001
"Permeation Emissions from Portable Fuel Containers", May 17, 1999
"Analysis of the Production of California Phase 3 Reformulated Gasoline with and without an Oxygen Waiver" by MathPro Inc., January 19, 2001
"draft Assessment of the Real World Impacts of Commingling Phase 3 reformulated Gasoline", CARB August 2003
"Program Report: Emission Impacts of Fuels to Accommodate the New York State Oxy-Waiver Request and MTBE Ban", NYSDEC, May 6, 2003
"Enclosure G" from NYSDEC's January 6, 2003 oxygenate waiver request, estimating increases from use of ethanol at various RVP levels.

Connecticut has followed with great interest congressional efforts over the years to eliminate the oxygen mandate from the reformulated gasoline requirements contained in the CAA. Connecticut appreciates recognition by Congress that this requirement is unnecessary, and applauds those efforts to remove this requirement from the CAA. However, a congressional solution will not be forthcoming, and Connecticut cannot wait any longer. In the many iterations of the renewable fuel standard legislation that have been drafted by Congress of the last several years, the one consistent element has been a commitment to eliminate the minimum oxygen requirement of the RFG program. It is recognized that the addition of oxygenate no longer provides benefits toward meeting the NAAQS, and could cause significant harm to the State.

The Connecticut Department of Environmental Protection (CTDEP) outlined, as part of Connecticut's initial request, how the continuation of an oxygenate requirement, when fulfilled by ethanol, could interfere with attainment of the National Ambient Air Quality Standards (NAAQS). CTDEP is concerned based on the body of technical information developed since the initial request submitted in 2002 that replacing one unnecessary component of gasoline with another would interfere with attainment of the NAAQS. Absent relief from the oxygen mandate, Connecticut is faced with a de facto ethanol mandate. Ethanol is the only oxygenate available in sufficient quantities to satisfy the mandate in place of MTBE and is currently blended at 10 percent by weight in the state. Connecticut supports a national increase in the use of renewable fuels such as ethanol. However, the introduction of significant amounts of ethanol should be phased-in nationally on a reasonable schedule and should be targeted to the right areas at the right time. Ethanol should not be arbitrarily forced into markets far from where it is produced, especially during the summer months when it poses adverse air quality impacts.

While ethanol appears certain to play a growing role in Connecticut gasoline, there are serious concerns regarding the public health impacts associated with the mandatory use of this additive in the summertime. Numerous technical studies have demonstrated that a summertime ethanol mandate will generate more air pollution and interfere with Connecticut's ability to attain the NAAQS for ozone and fine particles. The attached "Technical Rationale for Connecticut's Oxygen Waiver Request" dated April 2002 and updated here to incorporate new information describes the adverse air quality impacts that would result under an ethanol mandate. EPA is in a position to assist with Connecticut's ozone attainment efforts. Granting Connecticut's waiver will reduce the amount of ethanol in gasoline, thereby reducing evaporative emissions of volatile organic compounds (VOCs) which are ozone precursors and ultimately the amount of ozone formed in Connecticut.

In a clear demonstration of regional consensus, in the summer of 2001 the New England Governors issued *A resolution Regarding the Phase Down of MTBE and Lifting the Oxygen Mandate under the Federal Clean Air Act* (see attached). The resolution called on Congress to lift the oxygen mandate. Connecticut has also made clear that pending congressional action, EPA should grant individual state requests to waive the RFG program's oxygen requirement. In light of the body of evidence that has been added to the record, EPA should expeditiously approve Connecticut's request.

List of Attachments

- Connecticut Department of Environmental Protection's Letter to the Honorable Christine Todd Whitman, Administrator, U.S. EPA "Technical Rationale for Connecticut' s Oxygenate Waiver Request", April 22, 2002
- "Fuel Permeation From Automotive Systems", Final Report, September 2004
- "Demonstration that the U.S. Environmental Protection Agency Must Grant California A Waiver From the Federal Reformulated Gasoline Oxygenate Mandate on Remand From the U. S. Court of Appeals For the Ninth Circuit", December 2003
- "Background Information on Federal RFG Oxygenate Impacts on Particulate Matter", Revised September 19, 2003
- "Evaporative Emissions From Off road Equipment", June 21, 2001
- "Test Protocol and Results for the Determination of Permeation Rates from High Density Polyethylene Containers & Barrier Surface Treatment Feasibility Study", May 17, 1999
- "Analysis of the Production of California Phase 3 Reformulated Gasoline with and without an Oxygen Waiver by MathPro Inc.", January 19, 2001
- Draft Assessment of the Real World Impacts of Commingling Phase 3 reformulated Gasoline", CARB August 2003
- "Program Report: Emission Impacts of Fuels to Accommodate the New York State Oxy-Waiver Request and MTBE Ban", NYSDEC, May 6, 2003
- "Enclosure G" from NYSDEC's January 6, 2003 oxygenate waiver request, estimating increases from use of ethanol at various RVP levels.
- Oxygenated Fuels Association v. Pataki, US District Court, Northern District of New York, November 21, 2003
- Amicus Curiae Brief of the States of Connecticut, Maine, Massachusetts, New Hampshire and New York in Support of Reversal of EPA's Denial of California's request for a Waiver Under the Clean Air Act

STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD, CONNECTICUT
06106

JOHN G. ROWLAND
GOVERNOR

April 22, 2002

The Honorable Christine Todd Whitman
Administrator
U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Dear Administrator Whitman:

Pursuant to the authority provided in Section 211(k)(2)(B) of the Clean Air Act, the State of Connecticut plans to formally request a waiver of the federal reformulated gasoline (RFG) program's requirement that complying fuels contain a minimum of 2 percent oxygen by weight. The RFG program provides important public health benefits to the residents of Connecticut. While we are committed to maintaining the full measure of these clean air benefits, Connecticut is equally committed to protecting its precious water resources. MTBE, the additive used to meet the oxygen mandate, presents an unacceptable risk to the state's drinking water. Consequently, I signed into a law a provision that bans the use of MTBE as a gasoline additive beginning October 1, 2003.

Absent relief from the oxygen mandate, Connecticut will be faced with a de facto ethanol mandate since ethanol is the only oxygenate available to satisfy the mandate in place of MTBE. Connecticut supports a national increase in the use of renewable fuels balanced with a reasonable phase-in of renewable fuels. While ethanol appears certain to play a growing role in Connecticut gasoline, I have serious concerns regarding the public health impacts associated with the mandatory use of this additive in the summertime. My technical staff at the DEP will develop documentation to demonstrate that a summertime ethanol mandate will generate more air pollution and interfere with Connecticut's ability to attain the National Ambient Air Quality Standards for ozone and fine particulates. The attached document describes the adverse air quality impacts that would result under an ethanol mandate. In addition, I point your attention to the enclosed technical studies that have been conducted by our regional air and water quality associations, Northeastern States for Coordinated Air Use Management (NESCAUM) and New England Interstate Water Pollution Control Commission (NEIWPCC). These studies, commissioned by the New England Governors Conference, provide detailed analysis of the issues surrounding MTBE and ethanol in gasoline.

While air quality concerns are paramount in this request, I am also concerned about the negative economic impacts of requiring large quantities of ethanol in Connecticut regardless of cost. Significant infrastructure enhancements would be needed to transport, store and blend ethanol into gasoline. Further, there is considerable uncertainty regarding the ethanol industry's ability to produce sufficient quantities of competitively priced ethanol in the near-term. In these economic times, I believe that we all must be highly sensitive to the impact that our action or inaction will have on the public.

EPA demonstrated sensitivity to these concerns when acting to protect states in the upper Midwest from price spikes related to the use of ethanol in their fuel. As you recall, during the summer of 2000, gasoline prices in the Midwest increased more than 25 cents per gallon in less than a month. While there are several factors that may have played a role in the Midwest gasoline price spikes, the use of ethanol based RFG certainly contributed to the price increase. I request that the same sensitivity be afforded to states like Connecticut that seek to maintain reasonable gasoline prices without sacrificing environmental benefits.

In a clear demonstration of regional consensus, this past summer the other New England Governors and I issued *A Resolution Regarding the Phase Down of MTBE and Lifting the Oxygen Mandate under the Federal Clean Air Act* (see attached). In the resolution, we called on Congress to lift the oxygen mandate. We also made it clear that pending such action by Congress, the EPA should grant individual state requests to waive the RFG program's oxygen requirement.

No state should be forced to choose between clean air and clean water or between public health and environmental protection. It is simply not possible to protect air quality, water quality and Connecticut consumers absent relief from the oxygen mandate. As the date of Connecticut's MTBE ban is rapidly approaching, I urge EPA to evaluate this petition thoroughly and expeditiously.

Sincerely,

John G. Rowland

JOHN G. ROWLAND
Governor

JGR/JF/emw/rs
Enclosures

Technical Rationale for Connecticut's Oxygen Waiver Request

Introduction

Connecticut, along with several other states that participate in the federal reformulated gasoline (RFG) program, has taken action to ban Methyl Tertiary Butyl Ether (MTBE) as a fuel blendstock. Connecticut's MTBE ban, like those in other states, was enacted to address the unacceptable risk that MTBE poses to groundwater and potable resources. These concerns are effectively documented in the study and final Report of the Blue Ribbon Panel on oxygenates and gasoline that was conducted by the U.S. EPA and released in July of 1999. Information specific to the risks posed by MTBE in Connecticut and the Northeast region can be found in the study performed by the Northeast States for Coordinated Air Use Management (NESCAUM) entitled *RFG/MTBE Findings & Recommendations.*

MTBE bans leave ethanol as the only additive produced in sufficient quantities to meet the RFG mandate that complying fuels contain two- percent oxygen by weight. In Connecticut, the oxygen mandate will result in 75 to135 million gallons of ethanol entering the State's gasoline pool each year. The use of significant quantities of fuel ethanol will degrade the air quality of Connecticut.

Compared to MTBE and non-oxygenated fuels, gasoline containing ethanol will increase emissions of volatile organic compounds (VOCs), oxides of nitrogen (NOx) and several air toxics, particularly during the summer "ozone season." Increases in these pollutants will interfere with the state's ability to attain and maintain the federal ozone standard and undermine on-going efforts to reduce the public health risk from mobile source toxics. In spite of the tremendous improvements in air quality achieved over the last couple of decades, Connecticut has not yet attained the one-hour ozone standard and faces a difficult challenge to design a control program to meet the eight-hour standard. Preliminary data from 2001 ozone season show that the one-hour standard was exceeded on nine days in Connecticut, which includes seven days that the one-hour standard was exceeded in the New York City metropolitan area (which includes Fairfield County, CT). There were twenty-six days this past summer when the eight-hour ozone standard was exceeded in Connecticut. We also face the prospects of meeting a new fine particulate matter ($PM_{2.5}$) standard. Given that nitrates are a precursor to $PM_{2.5}$, any increase in NOx emissions associated with the introduction of large quantities of fuel ethanol will also interfere with Connecticut's ability to meet that National Ambient Air Quality Standards (NAAQS).

The adverse air quality impacts associated with ethanol usage can be diminished by exempting states and the petroleum sector from the use of ethanol in RFG during the summer months. Key to enabling an environmentally acceptable use of ethanol is granting a state's requested relief from the RFG program's oxygen requirements. According to the Clean Air Act, EPA can waive RFG's oxygen content requirement upon a demonstration that the presence of these compounds, at certain levels, prevent or interfere with a state's ability to attain or maintain a federal air quality standard.

The following discussion outlines the legal and technical arguments that require EPA to grant the state relief from the RFG program's 2 percent by weight oxygen requirement.

The Legal and Administrative Process for Obtaining a Waiver

EPA has provided little guidance or interpretation of the statutory language in §211(k)(2)(B) of the Clean Air Act, which states:

> *(t)he Administrator may waive, in whole or in part, the application of [the oxygenate requirement] for any ozone nonattainment area upon determination by the Administrator that compliance with such a requirement would prevent or interfere with the attainment by the area of a national primary ambient air quality standard.*

The statute's explicit allowance for EPA to grant state waiver requests on the basis of "interference," with attainment indicates that Connecticut need not demonstrate that the impacts of the oxygen requirement alone will prevent attainment or maintenance of a NAAQS. Instead, we must demonstrate that the oxygen mandate is obstructing or delaying attainment or maintenance of a single NAAQS. Connecticut must demonstrate that the use of ethanol to meet the oxygen requirement will increase emissions of the very pollutants that must be reduced in order for Connecticut to attain the current and imminent ozone and PM NAAQS.

Since a failure to decrease NOx and VOC emissions is cause for EPA sanctions, demonstrating a significant increase in these pollutants must be understood to interfere with attainment under §211(k)(2)(B). Connecticut's state implementation plan (SIP) demonstrates that in aggregate, a host of discrete control measures will bring the state into attainment of the ozone NAAQS according to the timelines set forth in the Clean Air Act. RFG is a primary component of Connecticut's effort to reduce emissions from motor vehicles, the largest source of ozone-forming pollutants in the state. Connecticut is legally obligated to achieve those reductions claimed in the SIP. The loss of projected benefits from any SIP control measures, such as limiting the effectiveness of the RFG program, must be offset by comparable reductions through other measures. Connecticut has implemented other emission control measures that have resulted in substantial reductions but there are not feasible measures to achieve additional significant reductions from stationary sources. Therefore, emission reductions must come from the mobile sector. Projected emissions increases associated with the oxygen mandate will interfere with Connecticut's ability to attain the ozone standard in a timely fashion. In a waiver request, the state will demonstrate that a measurable increase in ozone precursor pollutants would occur as a result of enforcing the RFG program's oxygen requirements in the presence of an MTBE ban.

Air Quality Basis for the Waiver

The state will show that the oxygen mandate adversely affects Connecticut's ability to control emissions of the NO_x and VOCs, the primary ozone precursors. Wide-scale replacement of MTBE with ethanol will result in increased emissions from vehicles operating on either RFG or conventional gasoline. Moreover, off-road gasoline equipment from jet-skis to lawnmowers will experience emission increases when ethanol is present in gasoline. These increases would come from: (1) tailpipe emissions; (2) evaporative emissions; and (3) indirect emissions from transporting hundreds of millions of gallons of ethanol to the Northeast by truck, barge and rail. The need for a waiver is predicated on the cumulative impact of excess emissions from all these sources. Under this weight of evidence approach, all potential sources of increased emissions will be explored and quantified, to the extent possible.

Increased Tailpipe Emissions

Waiver Basis #1: Increased NO_x Emissions not Captured in the Complex Model

The Phase II RFG regulations require refiners to achieve a 6.8 percent reduction in NO_x and a 27.4 percent reduction in VOC emissions compared to1990 levels, as calculated by EPA's Complex Model. Refiners will have to make other formulation changes to offset any increased tailpipe emissions associated with the addition of ethanol. However, there are data showing that the Complex Model, which is based on 1990 vehicle emissions and information, does not fully capture the effects that oxygenates, particularly ethanol, have on emissions from the current fleet of vehicles. Existing test data indicate that NO_x emissions from some newer technology vehicles increase with ethanol. These studies show that oxygenates increase NO_x emissions in a non-linear fashion. Little effect is seen until the oxygen content exceeds 2 percent by weight; beyond the 2 percent level, these studies show significant NOx increases. The data quantifying these effects, drawn from studies that included newer vehicles, are missing from the Complex Model. The effect appears to be particularly strong when ethanol is used as the oxygenate; with studies indicating that NO_x emissions may be more than 3 percent higher with ethanol as the oxygenate.

While the Complex Model does not fully capture the emission increases caused by oxygenates, these excess emissions can exacerbate ambient ozone concentrations. Consequently, Connecticut contends that the oxygen mandate creates a NO_x shortfall, since a portion of the emission reductions assumed in our SIP for the RFG program do not exist in the real world. Though it may be technically possible to remedy this shortfall through new fuel formulations that include oxygenates, a waiver of the minimum oxygen content requirement will allow our state to overcome these adverse impacts in a more timely and cost-effective manner. Denial of Connecticut's waiver request would interfere with our ability to make up the shortfall and attain the one-hour ozone standard by 2007, as required by the CAA.

Using available studies, Connecticut will document the increased NOx emissions that will occur from today's fleet of modern vehicles and seek to employ the California predictive model which incorporates some of these newer data to quantify the excess NOx emissions that will occur absent relief from the federal oxygen requirement.

Changes in Evaporative Hydrocarbon Emissions

The potential for changes in evaporative emissions due to the wide-scale replacement of MTBE with ethanol is likely to be more significant than the potential for changes in tailpipe emissions. However, these emission increases are difficult to quantify precisely. The federal RVP limits for summertime gasoline will constrain the potential increase in direct evaporative emissions from vehicles. However, the large-scale replacement of MTBE with ethanol to comply with the RFG program's minimum oxygen requirement could impact overall evaporative emissions by:

1. increasing evaporative emissions due to front-end volatility parameters that are not captured by refiner compliance models;
2. raising overall volatility when ethanol and non-ethanol blends are inadvertently *commingled* in vehicle fuel tanks; and
3. increasing fuel permeation through fuel lines and hoses and potentially impairing the performance of onboard vapor recovery systems.

Waiver Basis #2: General Increases in Evaporative Emissions

Increased evaporative emissions occur with ethanol blends compared to hydrocarbon (HC) fuels even when RVP is matched. Fuels with ethanol tend to increase front-end volatility parameters (i.e., the percentage evaporative emissions at 130 degrees F), even when both fuels have the same RVP. These volatility parameters are not included in the Complex Model, but are correlated with evaporative emissions that occur when the vehicle fuel system is heated above 100 degrees F during driving. Since fuel tanks can approach 120-130 degrees F on hot, summer days, conditions exist where ethanol fuels will have measurably higher evaporative emissions than equivalent HC fuels. Further, these emission increases would occur on days when the threat of an ozone episode is greatest.

Connecticut will present data that quantify the evaporative emission effect that ethanol has compared to HC blends. Using the projected fuel formulations discussed previously to establish the levels of ethanol expected in waiver and non-waiver scenarios, the state will estimate the evaporative HC increases that would occur on days when weather patterns are conducive to ozone formation. More evaporative emissions lead to more reactive mixing in the air that, on hot summer days, is most conducive at forming ground level ozone. Also, increased evaporative emissions would impair other states' (i.e., eastern Massachusetts and Rhode Island) ability to achieve compliance with the 1-hour ozone standard since they are marginally over the standard now and this increase could further delay their ability to attain the ozone standard.

Waiver Basis #3: Commingling

For areas with both RFG and conventional gasoline, the inadvertent commingling of ethanol and non-ethanol blended gasolines in automobile fuel tanks may result in significant increases in VOC emissions. Ethanol-blended RFG can be formulated to meet stringent RVP limits, at a cost, however, if even a small amount of it is subsequently mixed with a gasoline that is not similarly formulated for low RVP, the volatility of the overall mixture will increase. This would be the case if ethanol-blended RFG and conventional gasoline were inadvertently mixed in a vehicle fuel tank. It would also occur when MTBE and ethanol-based RFG are mixed, which will occur unless all states ban MTBE. Both of these scenarios are likely in Connecticut given the regional nature of the fuel distribution system in the Northeast. For example, this issue would be particularly problematic under a scenario where ethanol blends were used in Connecticut, conventional gasoline used in upstate New York and federal RFG containing MTBE sold in Massachusetts and Rhode Island. Contrary to EPA's determination in California, we will demonstrate, based on travel patterns and projected ethanol sales patterns that the co-mingling issue in Connecticut will be mitigated if the waiver is granted.

The potential emission impacts of fuel commingling have been explored in a number of studies. The Energy and Environmental Research Center at the University of North Dakota recently measured the RVP characteristics of a series of mixtures composed of non-ethanol gasoline and 10 percent ethanol blends (E-10). The unpublished results confirm that commingling increases RVP and evaporative hydrocarbon emissions. RVP increases were most pronounced when E-10 constituted 5 to 35 percent of the overall mixture; the effect was less pronounced when the ratio of E10 to non-ethanol blended gasoline exceeded 50 percent. Gasoline with an overall ethanol content of 2 percent by volume (achievable, for example, by mixing 20 percent E10 with 80 percent non-ethanol blended gasoline) showed RVP increases ranging from 0.66 to 0.93 psi over the base fuel RVP. According to the Complex Model, an RVP increase of 0.93 psi would increase VOCs by 14 percent, primarily from increased evaporative hydrocarbon emissions, for a typical summertime fuel in the Northeast.

An EPA study by Caffrey and Machiele estimates that the aggregate impact of commingling could increase RVP by 0.1 to over 0.4 psi "depending on assumptions for the market share of ethanol-containing gasolines, consumers' brand loyalty, and the distribution of fuel tank levels before and after refueling events." Caffrey and Machiele further concluded that RVP increases from commingling approach a maximum when the market share for ethanol blends reaches 30 to 50 percent, and decline thereafter as ethanol blends account for larger market shares.

To demonstrate commingling, Connecticut will:

(1) Project fuel formulations for both RFG and Conventional Gasoline (CG) markets. Once MTBE is banned, both RFG and CG markets will likely increase the use of ethanol as an octane enhancer. How much is used in each market and when during the year ethanol is used will be substantially affected by the presence or absence of the oxygen mandate. Other factors such as whether states allow the 1lb. RVP relaxation in CG will also be evaluated.

(2) Assess how much commingling takes place between RFG and CG markets. This task will require either regional studies or well-grounded assumptions on the refueling behavior of consumers, especially in Connecticut which borders RFG and conventional gasoline markets. It will also be necessary to examine interstate driving behavior that takes travelers through different markets in the Northeast; and

(3) Predict total increases in VOCs. Studies such as the Caffrey and Machiele study will provide a base for putting these data points together for emissions estimates.

Waiver Basis #4: *Other Evaporative Emissions Increases: Outside Vehicle Fuel Tanks, at Fueling Stations, from Non-Road engines, and via Impairment of On-Board Vapor Recovery (ORVR) Systems*

There are numerous smaller sources of emissions increases that will be caused by increasing the amount of ethanol in gasoline, from the impairment of various vapor recovery systems to increased evaporative emissions from non-road engines. Some of these effects have been studied. Others will need additional assessment to accurately quantify the impact.

The emission impacts of changes in fuel volatility will be limited to an extent by the presence of Stage II vapor recovery systems at refueling stations and increasingly by the advent of advanced on-board evaporative control systems. New "on-board vapor recovery" systems use carbon canisters to trap vapors from the fuel tank and are extremely effective at reducing evaporative emissions, achieving removal efficiencies as high as 98 percent. Such systems were introduced on new vehicles in 1998, but are not expected to fully penetrate the Northeast fleet until 2014, as much as a decade after Connecticut has phased out MTBE.

In all cars, even those without on-board vapor recovery, ethanol blends produce increased evaporative emissions from lines and hoses and from the engine crankcase. Ethanol molecules not only evaporate more readily than other fuel constituents, they are relatively small and hence more easily permeate rubber, plastics, and other materials found in components of the fuel delivery system. This may explain why, in hot soak evaporative hydrocarbon emissions tests for a car equipped with on-board vapor recovery, the reduction efficiency of the on-board system drop from a baseline of 98.7 to 96.3 percent when using a 10 percent ethanol blend. Recent data from several automakers suggests that the permeation effect is far greater than earlier believed. Finally, a related and perhaps more important issue concerns the potential for ethanol blends to degrade the performance of on board vapor recovery systems over time. Specifically, it has been suggested that ethanol blends could reduce the working capacity of the carbon canisters used in these systems because of ethanol's propensity to be tightly held by activated carbon and its tendency to attract water.

Ethanol may also effect the efficiency of Stage II enhanced vapor recovery (EVR) controls, though this potential impact will have to be explored in more depth.

Finally, gasoline is used in a variety of nonroad engines, including motor boats, jet skis, and lawn and garden equipment. Evaporative emissions from these engines are already relatively high and ethanol blends may exacerbate this problem. Unlike automobiles, the engines used in this equipment are not equipped with on-board vapor recovery systems. Further, their fuel tanks are not Stage II compatible. This effect is being explored by EPA's Office of Transportation and Air Quality.

<u>Emissions Increase Due to the Transport of Ethanol</u>

Waiver Basis #5: <u>*Emissions Associated With the Transport of Ethanol to and within the Northeast*</u>

A final category of emissions impacts associated with the wide-scale use of fuel ethanol in Connecticut relates to the transport of ethanol from production centers in the Midwest to gasoline distribution terminals in Connecticut and elsewhere in the Northeast. At present ethanol is not shipped via pipeline due to its affinity for water. Instead, ethanol is likely to be transported to the region by truck, barge, and rail.

Connecticut will demonstrate the impact of transporting ethanol by determining how much ethanol would be demanded both with the waiver and without the waiver. The state will use the calculations in NESCAUM's report, *Health and Economic Impacts of Adding Ethanol to Gasoline in the Northeast States,* to determine how much additional transportation would be required and how much this would increase emissions.

<u>Summary</u>

Connecticut will demonstrate that the 2 percent oxygen requirement in RFG causes excess emissions of precursor pollutants that interfere with Connecticut's ability to attain and maintain the ozone NAAQS. As outlined above, there are several different bases for demonstrating that the oxygen requirement, in the presence of the state's ban of MTBE, will result in increased emissions of ozone precursors. The weight of evidence to be outlined in a waiver request will demonstrate that the oxygen requirements of the RFG program interfere with Connecticut's ability to fulfill its requirements under the Clean Air Act.

NEW ENGLAND GOVERNORS' CONFERENCE, INC.

RESOLUTION NUMBER __158____

A Resolution Regarding the Phase Down of MTBE and Lifting the Oxygen Mandate under the Federal Clean Air Act

WHEREAS, the New England Governors' Conference, Inc. (NEGC) Committee on the Environment has endorsed the report entitled ***Health, Environmental, and Economic Impacts of Adding Ethanol to Gasoline in the Northeast States***, prepared by the New England Interstate Water Pollution Control Commission (NEIWPCC) and the Northeast States for Coordinated Air Use Management (NESCAUM), and the following conclusions from the study:

- *MTBE (methyl tertiary-butyl ether) has been beneficial to air quality* -The use of RFG (reformulated gasoline) in the Northeast has provided substantial reductions in smog forming emissions and has drastically reduced emissions of benzene and other known carcinogens found in vehicle exhaust.
- *MTBE has been harmful from a water quality perspective*- The unique characteristics of MTBE pose an unacceptable risk to the region's groundwater.
- *Economic implications of eliminating MTBE* - MTBE and ethanol are the only two oxygenates currently produced in quantities sufficient to meet the demand created by the RFG program. Therefore, under current federal law, eliminating MTBE represents a de facto mandate for ethanol. The consequences of introducing hundreds of millions of gallons of ethanol into the region's gasoline pool will have significant economic impacts. Conservative estimates cite potential increases of the cost of gasoline in the range of 3-11 cents per gallon; and

WHEREAS, MTBE has been the primary additive to fulfill the oxygenate requirement in the region, and in states that have passed legislation requiring a ban on gasoline containing MTBE, ethanol serves as a de facto mandate to meet a state's requirement for RFG;

NOW, THEREFORE, BE IT RESOLVED that the New England Governors' Conference, Inc. acknowledges the need for a coordinated strategy that includes congressional action to lift the oxygen mandate for RFG, and pending effective Congressional action, US EPA should grant individual state requests to waive the RFG program's oxygen requirements; and

BE IT FURTHER RESOLVED that in an effort to continue to pursue the mutually important goals of clean water and clean air, the New England Governors' Conference, Inc. directs its Committee on the Environment to work with their respective stakeholders to pursue a coordinated regional phase down of MTBE and establish an air toxic performance standard based on actual reductions achieved by RFG; and

BE IT FURTHER RESOLVED that the New England Governors will instruct their respective responsible agencies to develop a model waiver request and technical support documentation for interested states to utilize in pursuing a waiver of oxygen mandate; and

BE IT FURTHER RESOLVED that the New England Governors' Conference, Inc. directs its Committee on the Environment to diligently explore opportunities to develop local sources to produce fuel ethanol from cellulosic biomass in the region.

ADOPTION CERTIFIED BY THE NEW ENGLAND GOVERNORS' CONFERENCE, INC. ON August 7, 2001.

John G. Rowland
Governor of Connecticut
Chairman

FUEL PERMEATION
FROM AUTOMOTIVE SYSTEMS

Final Report

CRC Project No. E-65

September 2004

Prepared for:

California Environmental Protection Agency

Air Resources Board
1001 I Street - Sacramento, California 95814

and

Coordinating Research Council, Inc.
3650 Mansell Road, Suite 140 - Alpharetta, Georgia 30022

FUEL PERMEATION FROM AUTOMOTIVE SYSTEMS

Final Report

CRC Project No. E-65

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Abstract

The California Air Resources Board (CARB), in cooperation with the Coordinating Research Council (CRC), sponsored a major study on the permeation effects of ethanol on automotive fuel systems. Permeation is a diffusion process whereby fuel molecules migrate through the elastomeric materials (rubber and plastic parts) that make up the vehicle's fuel and fuel vapor systems. Permeation is a component of the evaporative emissions from the vehicle fleet.

The need for a study of the permeation effects of ethanol became apparent when in late 1999 California banned the use of MTBE in gasolines. With this ban, which became effective starting in calendar year 2004, ethanol became the only oxygenate approved for use in California gasolines. California must quantify the permeation effects of ethanol because California's statutes require that any increase in fuel emissions be off-set with a similar reduction from other sources. The year-round use of oxygenated gasoline in severe and extreme ozone non-attainment areas is a federal government requirement that applies to about 80 percent of the gasoline sold in California. The CARB petitioned the Environmental Protection Agency to waive the oxygenate requirement for California's gasoline, stating that complying gasolines could be blended without the use of an oxygenate. However, a waiver has not yet been granted.

The study was first proposed at a public meeting in Sacramento on June 21, 2001. The CRC offered to support and co-fund the program. Contracts were awarded in March 2002, but funding availability delayed the formal commitment until late in 2002.

This test program was designed to determine the magnitude of the permeation differences between three fuels, containing either MTBE, ethanol, or no oxygenate, in the selected test fleet. The testing was conducted on a sample of ten California vehicles chosen to represent the light-duty in-use fleet as it existed in calendar year 2001. The oldest was a 1978 Oldsmobile Cutlass, and the newest was a 2001 Toyota Tacoma pick-up truck. Vehicles were identified and purchased in late 2002.

The vehicle's liquid and vapor fuel systems were removed and installed on aluminum frames (rigs) for evaluation. Special care was taken to remove the complete system without disconnecting any of the components. The rig mounted systems were stabilized at 105°F with a 100% fill of each of the test fuels.

The emission tests were conducted between January 2003 and June 2004. Emission measurements included steady-state permeation rates at 105 and 85°F, and 48-hour diurnal measurements using the California test procedure (65 to 105 to 65°F). All emissions samples were analyzed for hydrocarbons and specific oxygenates, and average reactivities were calculated from the speciation results for all three fuels. Repeat diurnal tests were performed using the non-oxygenated fuel to establish an estimate of the repeatability of the experiment. The coefficient of variation (COV) (standard deviation/ mean level) for the diurnal results was estimated at 8%.

Emissions increased on all 10 vehicle fuel systems studied when ethanol replaced the MTBE in the test gasolines. The average permeation emissions with a 5.7 volume % ethanol gasoline were 1.40 grams/day higher than permeation emissions with the MTBE gasoline and 1.10 grams/day higher than permeation emissions with a non-oxygenated gasoline. This is equivalent to an average permeation emissions increase of 65% with a change from the MTBE gasoline to the ethanol gasoline and 45% with a change from the non-oxygenated gasoline to the ethanol gasoline. The average permeation difference between the MTBE fuel and the non-

oxygenate fuel was 0.30 grams/day. The differences between the ethanol fuel and the others are statistically significant at the 95% confidence level. The differences between the MTBE and the non-oxygenated fuel are not statistically significant. The results of this study apply to 5.7% ethanol blended gasoline as used in California, but may not necessarily apply to higher concentration ethanol blends or different gasoline compositions. This report with detailed results of the test program has been posted on the CRC's web-site at www.crcao.com and on CARB's web-site at www.arb.ca.gov/fuels/gasoline/gasoline.htm.

The rigs with non-metallic fuel tanks were evaluated to determine if permeation emissions varied with fill level. The base program stabilized the permeation at 100% fill. Additional testing was performed at 20% fill. Mixed results were obtained – the newer systems had less permeation after the 20% stabilization; the mid-90s tanks had little effect or an increase.

Introduction

California has achieved significant improvements in air quality in the last decade. An important contribution to the State's progress has been the regulation of gasoline properties to reduce motor vehicle emissions. California's Phase 1 gasoline regulation, which took effect in 1992, banned the use of lead, required the use of deposit control additives, and placed further limits on volatility. The Phase 2 regulations, which took effect in 1996, required extensive changes to gasoline composition, including specifications for oxygen at the levels required by the federal government. Under federal law as defined in the Clean Air Act Amendments of 1990 (Section 211 (k)(2)(B)), severe and extreme ozone non-attainment areas of the country are required to use "reformulated" gasoline as one of their attainment strategies. This reformulated gasoline must contain at least an average of 2% (by weight) oxygen year round. Two oxygenates are commonly used, Methyl Tertiary-Butyl Ether (MTBE) and ethanol (EtOH).

The effects of MTBE use were studied by University of California researchers, and based on the study's findings and public testimony, the governor issued Executive Order D-5-99, dated March 25, 1999, stating that there was a significant risk to the environment from using MTBE in gasoline in California. The Executive Order D-5-99 directed specific action to be taken by appropriate state agencies including the ARB to ban the use of MTBE and investigate the environmental effects of alternative oxygenates. Among other tasks, the ARB was specifically directed to do the following:

- Adopt Phase 3 (CaRFG3) regulations to provide flexibility in lowering or removing oxygenates while maintaining air quality benefits of the existing ReFormulated Gasoline program (RFG)
- Request a waiver from the federal year round oxygenate requirement on California's gasoline.

With the ban on MTBE effective December 31, 2003, ethanol is currently the only oxygenate approved for use in California gasoline. Under the governor's Executive Order, various state agencies evaluated the environmental impact of ethanol use. One impact of concern was the potential for ethanol-containing gasolines to increase the rate of permeation of fuel components through materials used in vehicle fuel systems. Permeation is the migration or diffusion of fuel molecules through the elastomeric materials (rubber and plastic parts) that make up the vehicle's fuel and fuel vapor systems. Permeation is a component of the daily evaporative emissions from a vehicle, but the effect due to ethanol use was not adequately quantified when the ARB adopted the Phase 3 RFG regulations in 1999. This report does not assess permeation emissions from non-automotive sources such as fuel storage and distribution facilities, portable storage containers, etc.

This test program, (CRC E-65 Program), was designed to determine the magnitude of the permeation effect on the selected vehicle systems. The objective was to measure the permeation emissions of California-compliant gasolines containing MTBE, ethanol, or no oxygenate in vehicle systems representative of the light-duty in-use fleet as it existed in calendar year 2001. The study was initiated by the CARB staff and proposed by Harold Haskew & Associates, Inc.[1] of Milford, MI at a public meeting in Sacramento on June 21, 2001. The CRC asked to participate and offered to co-fund the program. Harold Haskew was selected to provide the program administration. Automotive Testing Laboratories (ATL)[2] was selected to provide the testing services for the study. Contracts were awarded in March of 2002, but funding availability delayed the formal commitment until late in 2002. The emission tests were conducted during a period that ran between January 2003 and June 2004. This report presents the results of the experimental test program.

We offer page number references at each item to speed the reader to the pertinent section. Second, because of the voluminous data, we have offered example listings of the underlying data, and referred the reader to a "Companion CD-ROM", available through the CRC[3] by request, or available as a down-load from the CARB web-site (www.arb.ca.gov/fuels/gasoline/gasoline.htm). Third, we have included background information about permeation as a component of evaporative emissions, the SHED technique for measuring evaporative emissions, and the history of evaporative emission regulations.

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[2] Automotive Testing Laboratories, 263 S. Mulberry St., Mesa, AZ 85202 Phone (480) 649-7906

[3] Coordinating Research Council (CRC), 3650 Mansell Road, Suite 140, Alpharetta, GA 30022, (678) 795-0506, "www.CRCAO.com"

The CRC E-65 Project Steering Committee

The Coordinating Research Council (CRC) is a non-profit organization that directs, through committee action, engineering and environmental studies on the interaction between automotive equipment and petroleum products. The Sustaining Members of CRC are the American Petroleum Institute (API), the Society of Automotive Engineers (SAE) and a group of automobile manufacturers (Ford, General Motors, DaimlerChrysler, Honda, Toyota and Volkswagen).

The E-65 project was directed by a steering committee of 18 members, including representatives of vehicle manufacturers, the petroleum industry, CARB staff, and the Renewable Fuels Association.

Members were:

Gary Herwick Co-Chair	General Motors
Mike Ingham Co-Chair	ChevronTexaco
Brent Bailey	Coordinating Research Council
Loren Beard	DaimlerChrysler
Tim Belian	Coordinating Research Council
Steve Brisby	California Air Resources Board
Steve Cadle	General Motors
Dominic DiCicco	Ford Motor Company
King Eng	Shell Global Solutions
Frank Gerry	British Petroleum
Albert Hochhauser	ExxonMobil
Stuart Johnson	Volkswagen of America
David Lax	American Petroleum Institute
Hannah Murray	Toyota
Mani Natarajan	Marathon Ashland
Robert Reynolds	Renewable Fuels Association
Dean Simeroth	California Air Resources Board
Jim Uihlein	British Petroleum
Ken Wright	ConocoPhillips

Conclusions, Findings and Recommendations

Conclusions - Based on the results of this study, and subject to all the limitations of the project plan and scope, the following can be concluded:

1. Gasoline containing ethanol at a level of 2.0 weight percent oxygen increased the permeation of the tested California vehicle systems, compared to gasoline with MTBE as the oxygenate at the same oxygen content, or a similar gasoline made without any oxygenate; these changes in emissions were statistically significant at the 95% level for the diurnal data. The non-oxygenated fuel did not produce a statistically significant change in permeation relative to the MTBE fuel. (Page 39)
2. Non-ethanol hydrocarbon permeation emissions generally increased when the ethanol containing fuel was tested. (Pages 51-52)
3. The average specific reactivities of the permeate from the three test fuels were similar. The specific reactivities of the permeate of the MTBE and ethanol fuels (Fuels A and B) were not statistically different on average. The non-oxygenated fuel (Fuel C) permeate was higher than the other two with a statistically significant difference. (Pages 44-50)
4. Permeation rates measured at different temperatures followed the relationship predicted in the literature, nominally doubling for a 10° C rise in temperature. (Pages 53-55)
5. A consistent relationship between the 105°F steady-state permeation rate and the variable temperature 24-hour diurnal permeation rate was observed on all three fuels. (Page 56)
6. Vehicles certified to the newer "enhanced" evaporative emission standards (phased in from the 1996 to 1998 model years) had lower permeation emissions, including those with non-metallic fuel tanks. (Pages 39-40)
7. The non-metallic fuel tank systems of the early 1990s (Rigs 5 and 6) exhibited relatively high permeation emissions on all test fuels compared to the other systems tested. (Pages 39-40)
8. Permeation rates from the two newest non-metallic fuel tank systems (Rigs 2 and 4) exhibited a sensitivity to fill level. The emissions were lower when there was less fuel in the tank. (Page 59)
9. Permeation emissions (105°F steady-state) generally approached a stabilized level within 1 to 2 weeks when switching from one fuel to another. (Page 37)

Findings -

1. The average increase of the diurnal permeation emissions was 1.40 g/day for the ethanol fuel compared to the MTBE fuel (Fuel B compared to Fuel A). The individual rig increases ranged from 0.34 to 2.71 g/day. (Appendix G - Page 78)

2. The average increase of the diurnal permeation emissions was 1.10 g/day for the ethanol fuel compared to the non-oxygenated fuel (Fuel B compared to Fuel C). The individual rig increases ranged from –0.15 to 2.90 g/day. (Appendix G – Page 78)

3. The average specific reactivities (MIR – g Potential Ozone/g VOC) of the permeate emissions from the three fuels, and the 95% multiple comparison limits about those averages were found to be (Page 49):

MTBE Fuel	3.47 ± 0.107
Ethanol Fuel	3.27 ± 0.102
Non-Oxygenated Fuel	3.66 ± 0.075

4. The average 105°F steady-state permeation rates ranged from 9.4 to 801 milligrams per hour (mg/hour) on the ten rigs and the three tested fuels. (Page 53)

5. The ratios between the 85 and 105°F permeation rates, on average, were (Page 54):

MTBE Fuel	0.42
Ethanol Fuel	0.46
Non-Oxygenated Fuel	0.46

Recommendations – *It is recommended that this study be expanded to assess the newer California LEV II compliant vehicles.* The data and understandings collected during this test program are limited to the in-use fleet vehicles that existed at the time this study was initiated. The California LEV II requirements lowered the evaporative emissions (3-day Diurnal + Hot Soak) limits from 2.0 g/day to 0.5 g/day starting with model year 2004 vehicles. These new technology vehicles should be evaluated in the same fashion as was done in this study

It is also recommended that a similar study be done on E10 fuel. While the data were collected at ethanol levels currently used in California (5.7%), ethanol is commonly used at 10% in other parts of the country.

Test Program Overview

The objective of this test program was to measure the permeation emissions of California compliant gasolines containing ethanol, MTBE, or no oxygenate, in vehicle systems representative of the California in-use fleet as it existed in calendar year 2001.

A test fleet of 10 vehicles was chosen. ATL procured the vehicles for testing from California retail sources, brought the vehicles to the laboratory in Arizona, and carefully inspected the vehicles to insure that the original fuel system was present and in good repair. After passing this initial inspection, the lab personnel removed the entire fuel system intact (without making any disconnections to the liquid or vapor system), and fabricated an aluminum rack or "rig" that held the components in their approximate x, y and z positions.

Each test rig was filled with test fuel and stored in a test room at 105°F until evaporative testing determined that stabilization of the permeation emissions was achieved. Each rig had the fuel in it circulated twice a week, and all fuel was drained and fresh fuel was installed every seventh week. Once each week, each rig was removed from the soak chamber, and placed in a hot soak SHED[4] at a temperature of 105°F for 3 hours to estimate the current permeation rate.

After the rig's permeation rate was stabilized at 105°F, and approved by the Steering Committee, it was tested at 85°F and then prepared for a California 2-day diurnal (65 to 105 to 65°F) emission test.

The constant temperature tests were performed in a 105°F or 85°F hot soak SHED[5] for a three-hour test period, with the emissions measured during the last two hours. All fixed temperature (105° and 85°F) testing was performed in ATL SHED 14. Variable temperature diurnal (65° to 105° to 65°F) testing was performed in ATL SHEDs 13 and 15. These three SHEDS are variable volume/variable temperature (VV/VT) equipment that can be operated in fixed or variable temperature modes.

The fuel tanks and the canisters were vented to the outside of the SHED to eliminate the possibility of the tank venting emissions being counted as permeation. Emission rates were calculated using the 2001 California certification test procedure.

The fuel was drained from the rig, and a 40% fresh fill of the appropriate test fuel added. The rig was then placed in a VT-SHED, the canister vented to the outside, and the California 2-day diurnal procedure performed. Samples of the ambient air in the VT-SHED[5] were taken at the start of the diurnal and at the end of day 1 and day 2 for later hydrocarbon speciation analysis.

The details of the procedures are shown schematically in Chart 1 through Chart 8.

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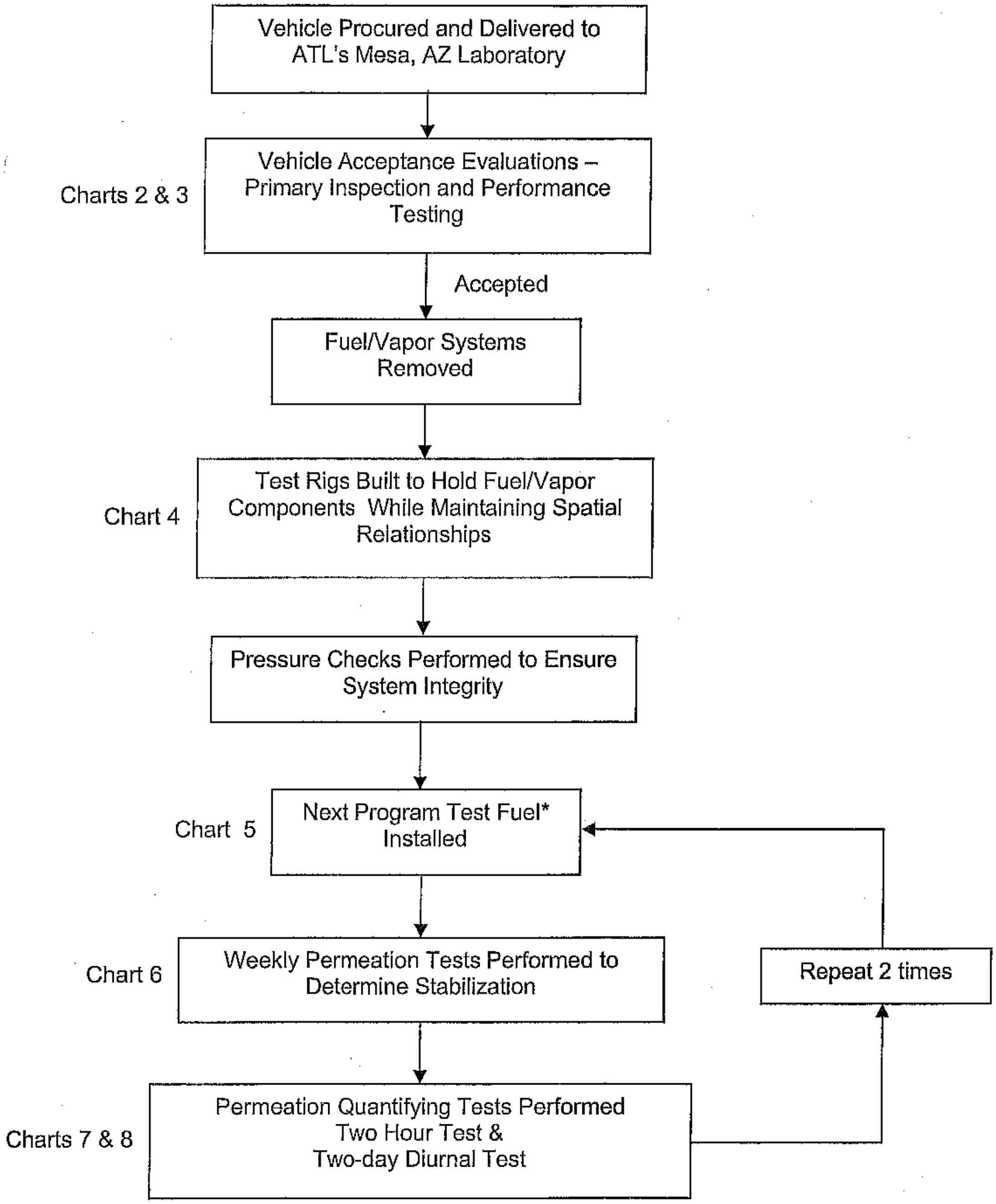
[4] SHED – Sealed Housing for Evaporative Determination

[5] A hot soak SHED is used for constant temperature evaporative emission tests. A variable temperature SHED (VT-SHED) differs in that it has hardware capable of changing the internal ambient temperature as required, and a means for compensating for the volume change associated with that temperature change. A 65 to 105°F temperature swing produces a 7.6% volume change, if the pressure remains constant. A VT-SHED can be used to conduct a constant temperature test.

Chart 1

E65 Program Overview



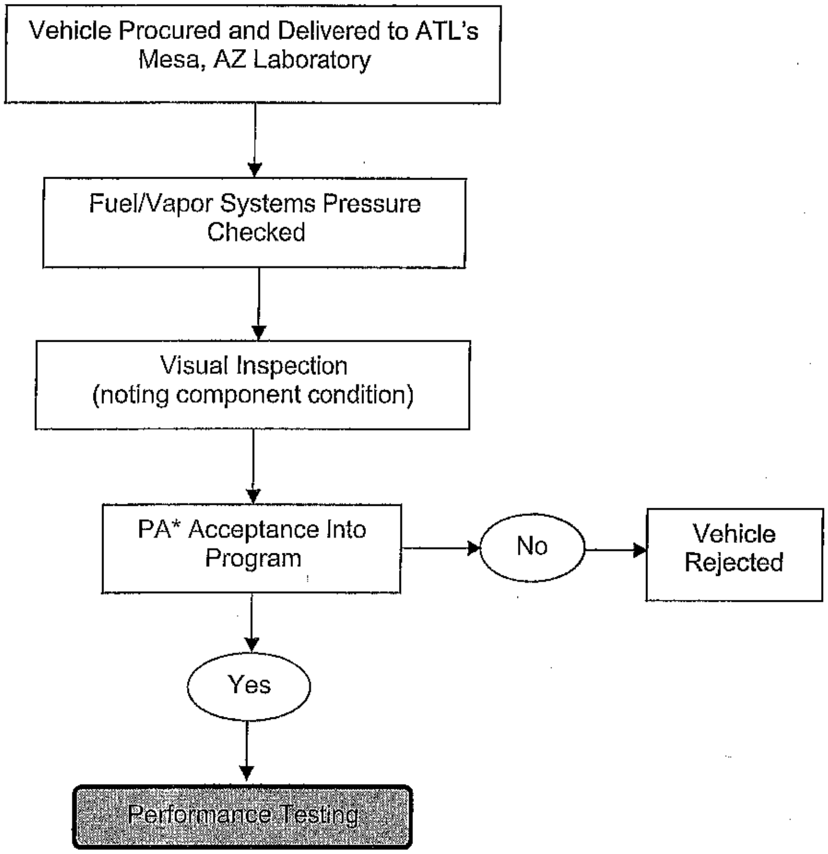
* Program Test Fuels

1. California Fuel w/~11 vol% MTBE
2. California Fuel w/~5.7 vol% Ethanol
3. California Type Non-Oxygenated Fuel

Chart 2

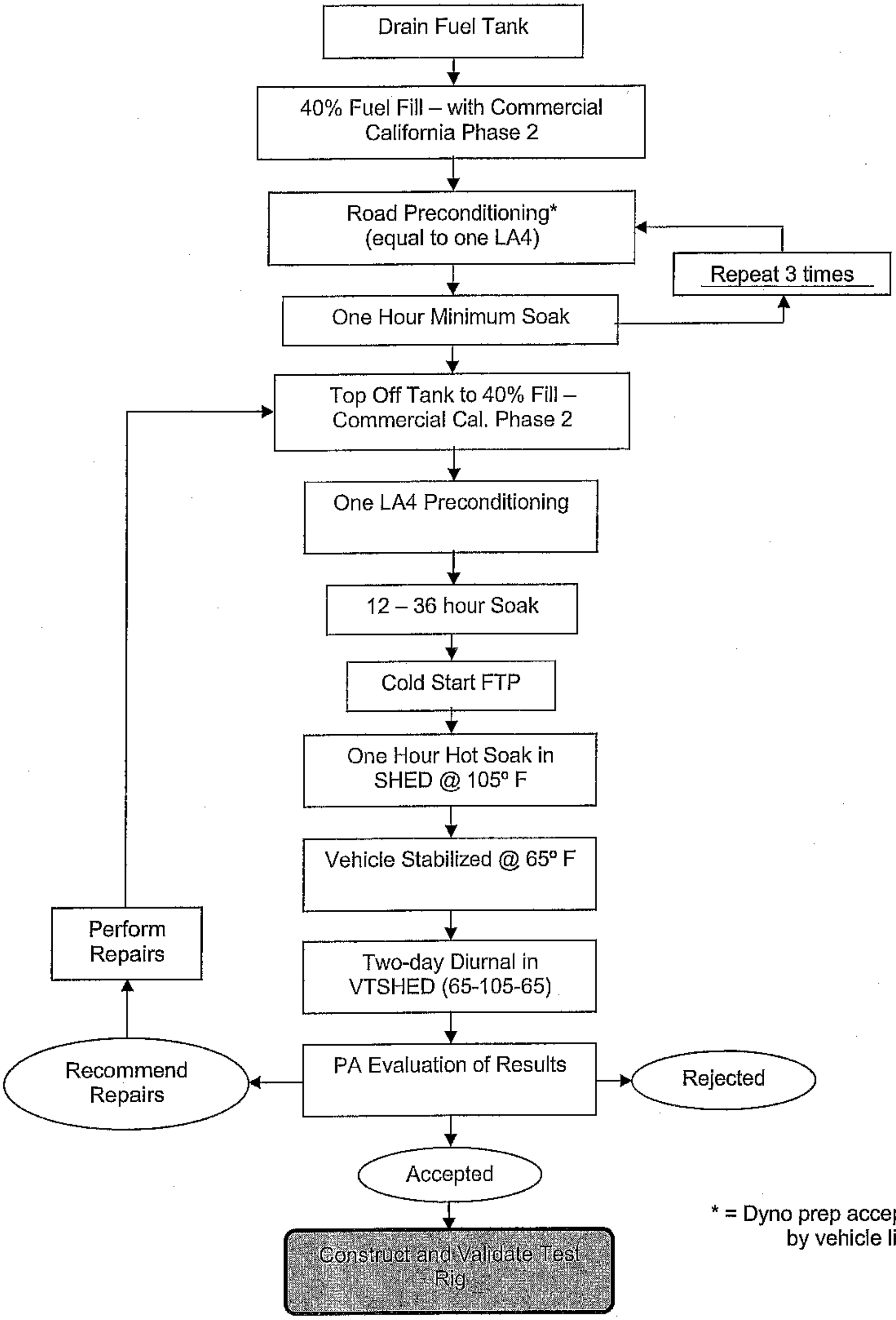
Vehicle Acceptance Evaluation

Step 1 – Procurement and Primary Inspection



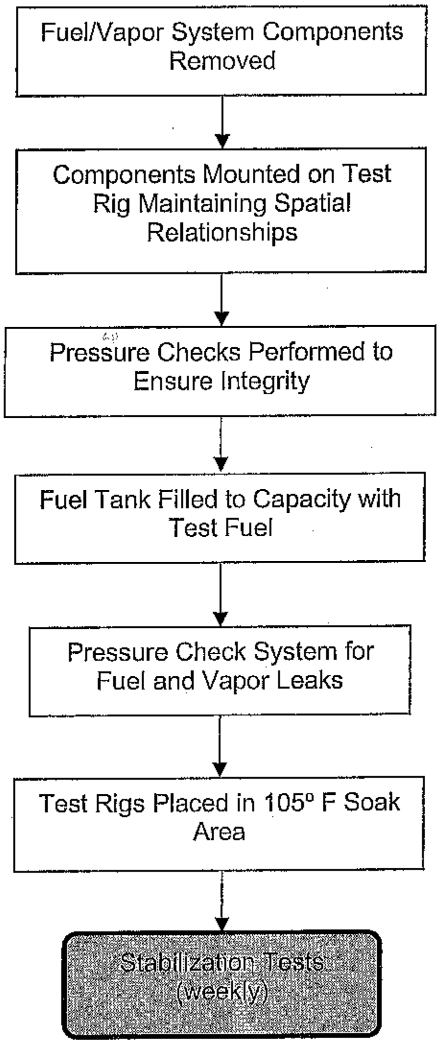
* = Program Administrator

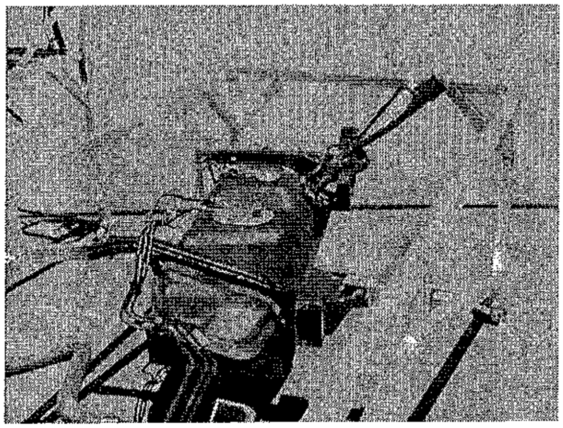
Chart 3
Vehicle Acceptance Evaluation
Step 2 - Performance Testing



* = Dyno prep acceptable if dictated by vehicle licensing

Chart 4
Construct and Validate Test Rig





Typical Test Rig

Chart 5
Test Fuel Change and Stabilization

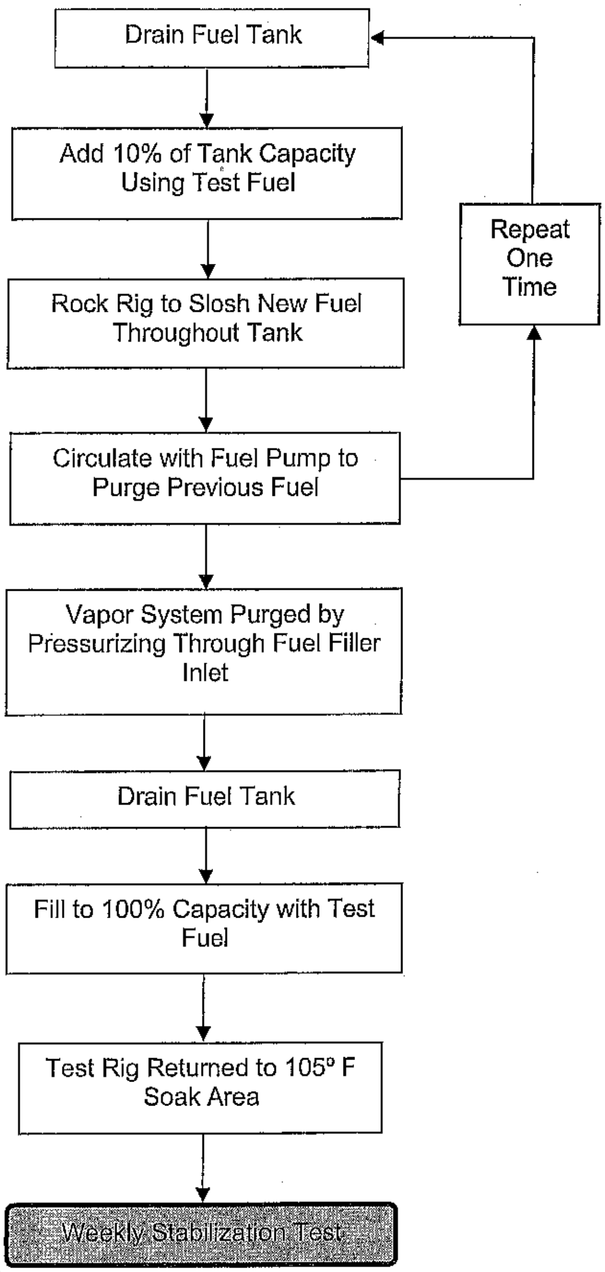


Chart 6
Weekly Stabilization Test

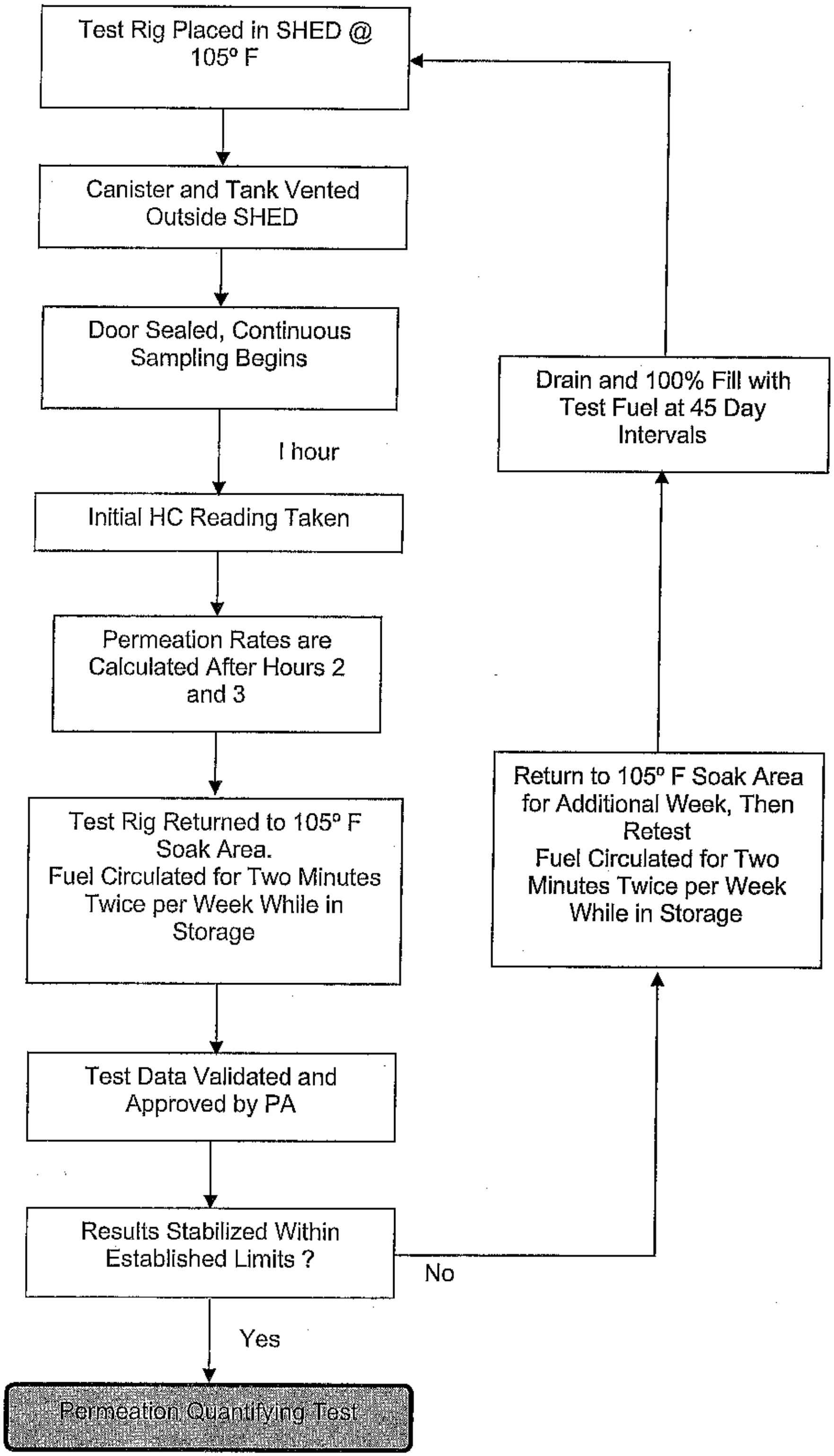


Chart 7
Permeation Quantifying Test

Step 1 – Two Temperature Permeation Test

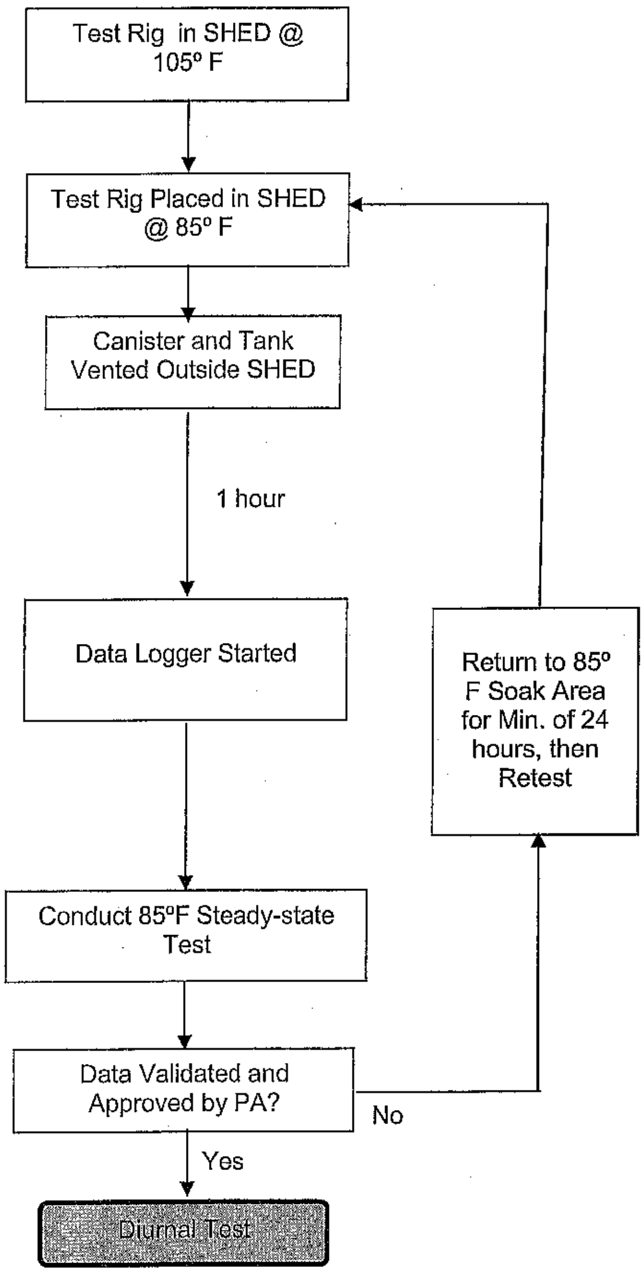
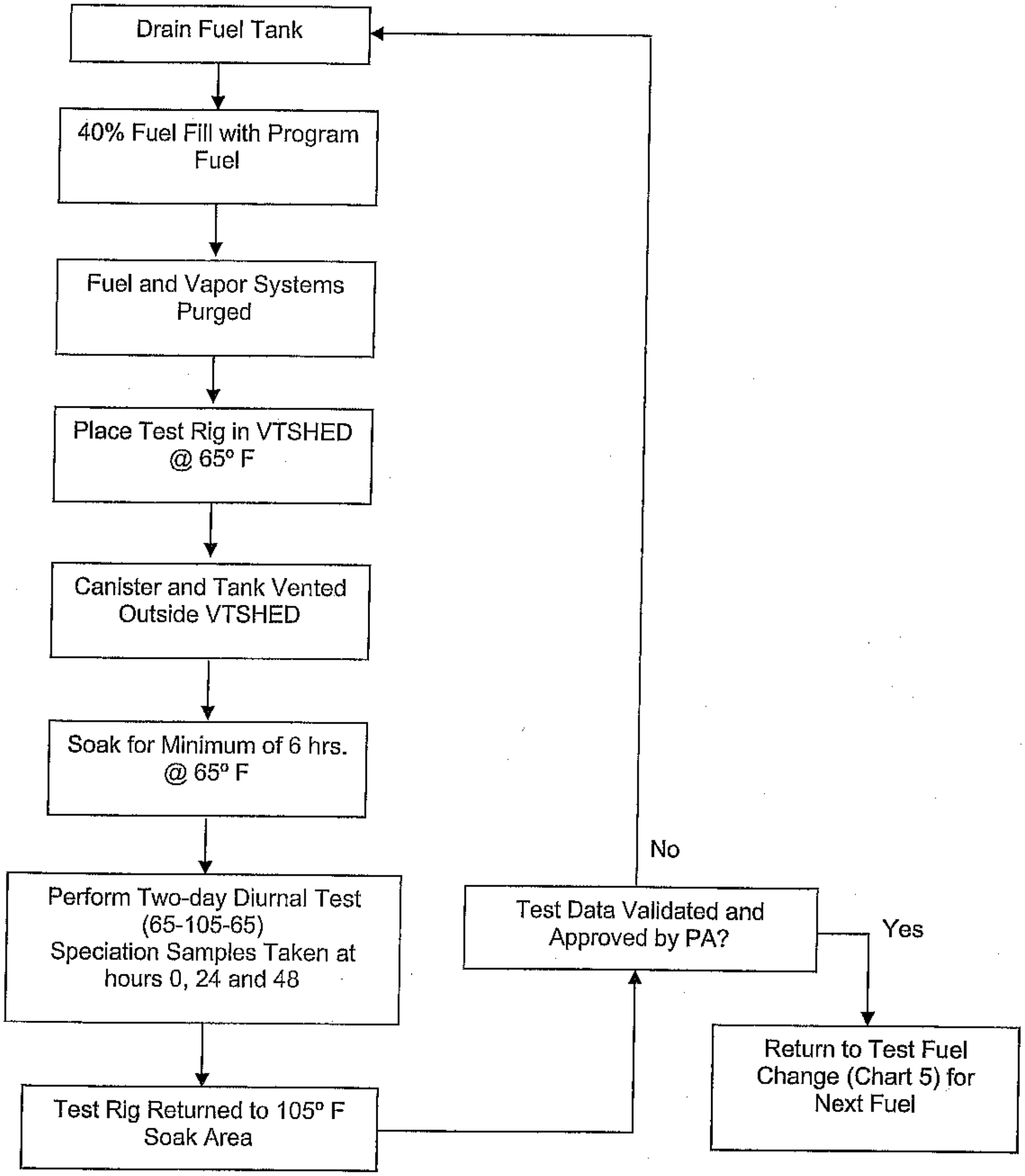


Chart 8
Permeation Quantifying Test
Step 2 - Diurnal Test



Fleet Selection

Figure 1 – Vehicle Teardown

A ten vehicle sample was selected to represent the range of light-duty vehicle technologies and ages that existed in the California in-use fleet in calendar year 2001. The sample size represented a pragmatic choice between manageability, cost, and a reasonable cross-section of vehicles.

A 2001 summary of gasoline-fueled passenger cars and light-duty trucks registered in California was furnished by Mark Carlock, Chief, Mobile Source Analysis Branch, Planning and Technical Support Division, CARB. We divided the sorted list into 10 deciles, grouped by model year as shown in Figure 2. The oldest 10% were vehicles from the pre-1983 model year – more than 20 years old. The pre-1970 model year vehicles had no evaporative emission controls at all. The 1970 to 1980 models had only the simplest of controls -- basically a carbon canister to contain the daily diurnal vapors.

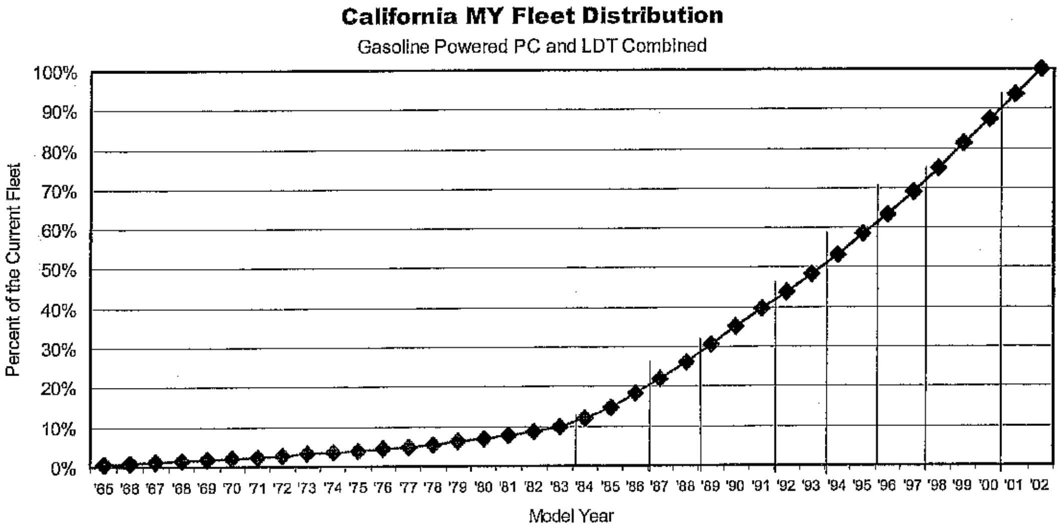


Figure 2

The project committee selected one vehicle from each of the model year decile groups. It was decided to balance the vehicle mix between cars, and light-duty trucks, which includes vans and sport utility vehicles. Choices were restricted to popular high-volume models that would be available in the existing population.

The test vehicle requirements were:

- Must be a California model from the California population
- Must have all the original evaporative control equipment present and functioning
- Must be in good mechanical condition, with no fuel system leaks

The final selection is listed in Table 1:

Table 1
E-65 Test Fleet Vehicles

Model Year	Vehicle Model	Rig No.
2001	Toyota Tacoma (P/U)	1
2000	Honda Odyssey (Van)	2
1999	Toyota Corolla	3
1997	Chrysler Town and Country (Van)	4
1995	Ford Ranger (P/U)	5
1993	Chevrolet Caprice	6
1991	Honda Accord	7
1989	Ford Taurus	8
1985	Nissan Sentra	9
1978	Oldsmobile Cutlass	10

Six passenger cars and four trucks were chosen. Four vehicles had non-metallic fuel tanks – the Honda Odyssey (Rig 2), the Chrysler Town and Country (Rig 4), the Ford Ranger (Rig 5), and the Chevrolet Caprice (Rig 6). The significance of the tank material is that permeation is a function of surface area, and a fuel tank is the largest surface area component of the vehicle's fuel and vapor system.

Rigs 1 through 8 were purchased from dealers -- 9 and 10 (the oldest vehicles) were purchased from private parties. Lab personnel traveled to inspect the vehicles to insure that they were suitable for the project. The newest 4 vehicles were driven from California to the Mesa, Arizona test facility, stopping at the California border to fill the tank with California conforming gasoline. The older vehicles (5 through 10) were trailered from California to the laboratory, again, filling with California fuel near the border to keep the permeation rate consistent with the California type fuel.

The odometers on the fleet ranged from 15,000 miles on the newest vehicle, the 2001 Toyota Tacoma, to 143,000 miles on the 1985 Nissan Sentra. Six vehicles had odometers over 100k miles. The oldest vehicle, the 1978 Oldsmobile Cutlass had 58k miles. Detailed test vehicle specifications are shown on Table 2.

Table 2
E-65 Fleet Specifications

													Enhan.	
Veh				Engine Size		Fuel				Tank	40%	Plastic	Evap/	
No.	Yr	Make/	Model	CID	L	Sys.	Odo.	Engine Family	Evap Family	Size	Fill	Metal	ORVR	VIN
							miles			gallons				
001	2001	Toyota	Tacoma	146	2.4	PFI	15,460	1TYXT02.4FFH	1TYXE0095AE0	15.8	6.3	Metal	Enh.	5TENL42N01Z718176
002	2000	Honda	Odyssey	214	3.5	PFI	119,495	YHNXT03.5EA3	YHNXE0130AAE	20.0	8.0	Plastic	Enh.	2HKRL1852YH518467
003	1999	Toyota	Corolla	110	1.8	PFI	77,788	XTYXV01.8DXB	XTYXR0115AK1	13.2	5.3	Metal	ORVR	1NXBR12EXXZ279565
004	1997	Chrysler	Town & Country	232	3.8	PFI	71,181	VCR23228G1EK	VCR1098AYP1A	20.0	8.0	Plastic	neither	1C4GP64L7VB367264
005	1995	Ford	Ranger	140	2.3	PFI	113,077	SFM2.318G1EK	SFM1045AYP0A	16.5	6.6	Plastic	neither	1FTCR14A6SPA11610
006	1993	Chevrolet	Caprice Classic	305	5.0	TBI	100,836	P1G5.7W5XEA9	PB0-1A	23.0	9.2	Plastic	neither	1G1BL53E9PR134928
007	1991	Honda	Accord LX	134	2.2	PFI	136,561	MHN2.2V5PC2	91FG	17.0	6.8	Metal	neither	JHMCB7659MC054984
008	1989	Ford	Taurus GL	182	3.0	PFI	110,623	KFM3.0V5FED8	9HM	16.0	6.4	Metal	neither	1FABP52U2KG140620
009	1985	Nissan	Sentra	98	1.6	Carb	142,987	FNS1.6V9FBC2	5ECC-3	13.2	5.3	Metal	neither	JN1PB15S3FU166896
010	1978	Olds.	Cutlass	262	4.3	Carb	58,324	830H2U	78BD	18.1	7.2	Metal	neither	3R47F8G439470

The vehicles represented by the three newest rigs, (1999 MY = Rig 3, 2000 MY = Rig 2, and 2001 MY = Rig 1), were all certified to the "enhanced" evaporative emission requirements (CA LEV) and were developed against a 24 hour[6] diurnal requirement. The evaporative emissions certification procedures used for the earlier model year vehicles represented in this study measured permeation during a 1 hour hot soak, and a "compressed-time" one hour diurnal. The enhanced test procedures put more emphasis on control of permeation in real-time.

Rig 4, the fuel system from a 1997 Chrysler Town and Country Van, was not certified to the "enhanced evap" standards, but clearly had advanced hardware fitted in anticipation of the up-coming regulations. This was verified by the DaimlerChrysler representative to the Steering Committee.

The 1993 MY Rig 6, and 1995 MY Rig 5 featured non-metallic fuel tanks of blow-molded high-density polyethylene construction. Rig 6 used a fluorination surface treatment on the inside of the tank to lower the permeation.

Each vehicle was given a complete inspection when it arrived at the lab to verify that all the emission components were present, and in good repair. The fuel system was pressure checked, and an engineering-type one-day diurnal test was performed to insure that the vehicle was suitable for the program. One vehicle was rejected after receipt at the lab, which required obtaining another candidate.

Test Rig Construction

Fuel system test "rigs" are used in the automotive development process to isolate the fuel system's contribution to the emissions. Since tires, adhesives, paint and vinyl trim can also emit hydrocarbons, they need to be removed to provide a better chance of properly identifying the fuel-related emissions. Isolating the fuel system components on a "rig" was the appropriate choice.

Refueling vapor controls are commonly developed in the automotive industry using rigs, or "test bucks", but they feature only the tank and canister system, with the carbon canister located close to the tank. This project included the fuel and vapor lines, and their chassis to engine connection hoses at the front of the vehicle.

All the fuel system components that could contribute to permeation losses had to be kept in the original spatial relationship. This meant that the rigs were almost as long as the vehicles. For system integrity, all components were removed and remounted without any disconnections. The photo of Rig 9 in Figure 3 shows one of the results.

In all cases, the vehicle was sacrificed, and the remaining parts and pieces sold to a scrap dealer. The Caprice and the Cutlass were bodies-on-frame, and required significant effort with a power saw to cut away the frame to allow the fuel lines to come free. The test rig frame was constructed of 1.5" square aluminum tube, with metal caster wheels at the 4 corners. Additional photos of some of the components are shown in Figures 4 and 5.

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[6] The vehicle is tested for up to three days in the SHED. The highest day's value (24 hour period) is used to determine compliance with the standard.

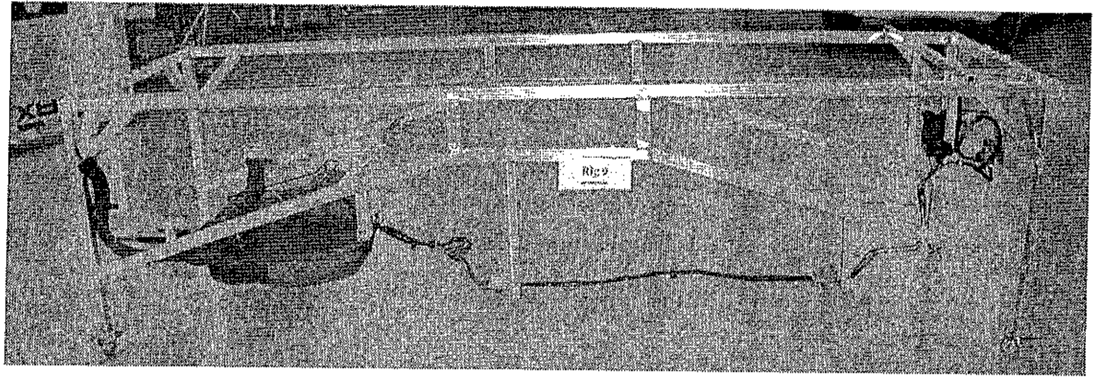

Figure 3. Test Rig 9

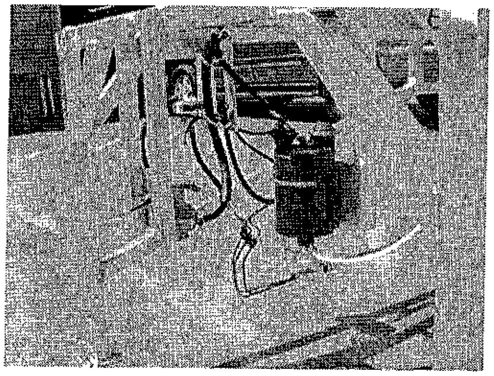

Figure 4. Canister and Controls Mounting

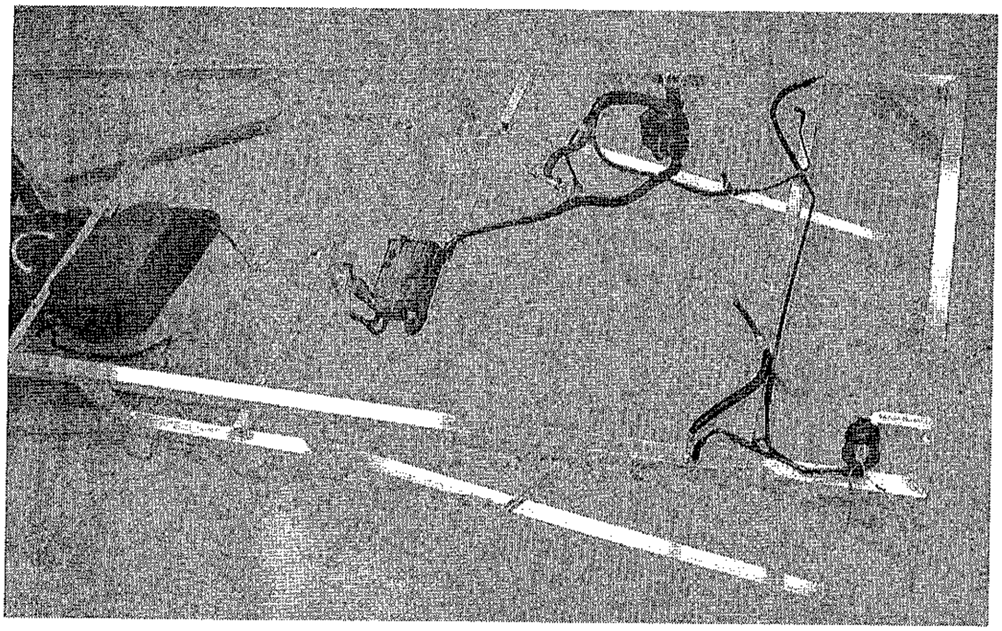

Figure 5. Test Rig 4

A complete set of the rig photos is available at www.arb.ca.gov/fuels/gasoline/gasoline.htm.

Fuel Properties

The project required three matched fuels – two with 2 weight percent oxygen, and a matching non-oxygenated fuel. The fuels were called A, B and C, and were tested in the following order:

1. MTBE containing fuel (2 wt.% oxygen) (Fuel A)
2. Ethanol containing fuel (2 wt.% oxygen) (Fuel B)
3. Non-oxygenated fuel (Fuel C)

Commercial fuels expected to meet these requirements were obtained by ChevronTexaco from terminals and inspected, including detailed hydrocarbon analyses. Based on these inspections, adjustments were made. The three test fuels were prepared with volatilities matched to the extent possible. The parameters that were matched included, in order of importance, RVP, T10, T50, T90.

Fuel A was found to contain too much oxygen and was lower in toluene content than the other fuels. Therefore, toluene and isopentane were added to lower the oxygen content and increase the toluene content while maintaining the vapor pressure. Fuel B was found to be much lower in olefins content than the other fuels so light FCC naphtha was added. Ethanol was added to the adjusted blend to bring its oxygen content back to 2.0 wt %. Fuel B was obtained without the required deposit control additive. The same deposit control additive present in Fuels A and C was added to Fuel B at the same use concentration so there would be no deposit control additive difference among the fuels. No adjustments were made to Fuel C.

ChevronTexaco supplied complete chemical speciation results for the three fuels as liquids. A short summary of the speciations is presented in Table 3. The various HC species in Fuel A were ranked and tabulated by their weight % in the fuel. Fuel B and C species are aligned with the same species in Fuel A to allow a direct comparison of the composition of the three fuels. The complete speciation listings for the three liquid fuels are contained in a Microsoft Excel™ file on the companion CR-ROM as "Liquid Fuel Speciation.xls."

A fuel acceptance panel consisting of four laboratories inspected the three test fuels. The average results of these inspections are shown in Table 4. The individual inspections obtained by each laboratory are shown in Appendix H. The same standard ASTM test methods were used by all laboratories. Distillation results were not provided by one laboratory because of analytical problems with the test method. The results indicate that the vapor pressures, 10% evaporated points, 50% evaporated points, and 90% evaporated points were matched to the extent possible while trying to keep the aromatics and olefins contents similar.

A summary analysis of the three test fuels classified by major hydrocarbon category and carbon number is shown in Table 5.

Table 3

Liquid Fuel Speciation Comparison – Top 46 Components
Fuel A Hydrocarbon Species Sorted by Weight % in the Liquid
Fuels B and C Components Aligned with Fuel A

	Fuel A	Fuel B	Fuel C
Species	Wt.%	Wt.%	Wt.%
Oxygenates			
MTBE	10.50	0.00	0.00
TAME	1.12	0.00	0.00
Ethanol	0.00	5.86	0.00
Hydrocarbon Species			
Toluene	9.61	8.06	9.98
2-methylbutane	9.07	6.64	10.86
2-methylpentane	4.42	5.21	6.98
m-Xylene	3.72	4.69	5.63
3-methylpentane	2.73	3.36	4.22
Pentane	2.69	2.23	3.84
Methylcyclopentane	2.54	2.84	3.39
124-TriMe-benzene	2.38	2.58	2.42
Hexane	2.00	1.66	2.59
o-Xylene	1.76	2.13	2.60
224-triMe-pentane	1.63	3.64	2.19
3-methylhexane	1.59	2.81	2.12
Methylcyclohexane	1.52	3.16	0.90
1-Me-3-Et-benzene	1.49	1.65	1.52
2-methylhexane	1.46	2.51	1.79
2,3-dimethylbutane	1.29	1.40	2.03
2,3-dimethylpentane	1.18	1.75	1.51
Ethylbenzene	1.18	1.42	1.84
Heptane	1.17	2.90	1.20
Cyclohexane	1.15	1.12	1.91
p-Xylene	1.14	1.45	1.53
2-Methylheptane	0.91	0.70	0.66
3-methylheptane	0.86	0.76	0.76
2,2-dimethylbutane	0.80	1.07	1.47
233-triMe-pentane	0.79	1.30	1.17
234-triMe-pentane	0.77	1.38	1.02
135-triMe-benzene	0.74	0.86	0.76
Butane	0.67	0.72	0.68
Octane	0.66	0.45	0.37
Benzene	0.64	0.86	0.85
1-Me-4-Et-benzene	0.61	0.73	0.66
1C3-diMecyclopentane	0.58	0.90	0.39
2,4-dimethylpentane	0.56	0.67	0.69
225-trimethylhexane	0.53	0.36	0.95
1-Me-2-Et-benzene	0.52	0.53	0.51
Propylbenzene	0.51	0.45	0.43

1T3-diMecyclopentane	0.50	0.78	0.33
123-triMe-benzene	0.48	0.48	0.48
2-methyl-2-butene	0.48	0.54	0.47
1T2-diMecyclopentane	0.46	0.83	0.26
Cyclopentane	0.46	0.40	0.54
2-Me-3-Et-pentane	0.42	0.52	0.45
2,4-dimethylhexane	0.41	0.59	0.44
2,5-dimethylhexane	0.38	0.50	0.40
% of Fuel	81.1	85.5	85.8

The 5.86 weight percent concentration of ethanol corresponds to 2.0 weight percent oxygen in Fuel B.

Table 4

CRC E-65 Permeation Study Fuel Inspections

(Average of Four Laboratories)

Inspection	Units	Fuel A CARB 2 MTBE	Fuel B CARB 3 Ethanol	Fuel C CARB 2 Non-Oxy
API Gravity	°API	58.8	58.2	61.0
Relative Density	60/60°F	0.7437	0.7461	0.7352
DVPE	psi	7.05	7.12	7.03
Oxygenates--D 4815				
MTBE	vol%	9.88	<0.1	0.04
TAME	vol%	1.13	<0.1	0.02
EtOH	vol%	0.0	5.46	0.0
O2	wt%	1.98	2.02	0.01
FIAM Corrected--D 1319				
Aromatics	vol%	22.9	25.9	26.7
Olefins	vol%	5.0	5.8	6.0
Saturates	vol%	61.1	62.8	67.3
Oxygenates	vol%	11.0	5.46	0.07
Aromatics--D 5580				
Benzene	vol%	0.53	0.72	0.73
Toluene	vol%	8.26	6.90	8.46
Ethylbenzene	vol%	0.91	1.12	1.45
p/m-Xylene	vol%	3.82	4.91	5.71
o-Xylene	vol%	1.42	1.76	2.11
C9+	vol%	8.59	10.13	7.62
Total	vol%	24.26	26.24	27.20
D 86 Distillation*				
IBP	°F	100.7	108.5	101.0
5% Evaporated	°F	126.1	128.7	128.0
10% Evaporated	°F	135.8	133.8	136.3
20% Evaporated	°F	147.8	140.1	147.9
30% Evaporated	°F	160.7	155.4	160.4
40% Evaporated	°F	176.5	184.5	175.4
50% Evaporated	°F	195.7	202.8	193.1
60% Evaporated	°F	219.2	218.4	213.3
70% Evaporated	°F	243.7	235.8	236.3
80% Evaporated	°F	270.0	261.2	262.4
90% Evaporated	°F	308.8	304.0	297.9
95% Evaporated	°F	333.4	332.2	324.0
EP	°F	373.0	385.7	366.3
Recovery	vol%	97.4	98.1	97.9
Residue	vol%	1.4	1.0	0.9
Loss	vol%	1.2	0.9	1.2
Gum				
Unwashed	mg/100ml	16.8	19.1	18.5
Washed	mg/100ml	1.0	0.5	0.6
Sulfur	ppm	25.7	14.7	17.7

* One lab did not provide inspections of this property.

Table 5

CRC E-65 Permeation Study
Test Fuel Detailed Hydrocarbon Analysis

FUEL A -- CARB 2 MTBE - BY VOLUME% and CARBON NUMBER:

CARBON NUMBER	N-Paraffin	Iso-Paraffin	Olefins	Naphthas	Aromatics	Oxygenate	Un-Classified	Total Per Carbon
C3-	0.01							0.01
C4	0.86	0.10	0.05			0.01		1.02
C5	3.17	10.80	1.36	0.45		10.45		26.23
C6	2.23	10.36	1.55	3.59	0.54	1.07		19.34
C7	1.26	5.50	0.64	3.33	8.19			18.93
C8	0.69	7.00	0.53	2.12	6.63		0.01	16.99
C9	0.39	3.09		0.57	6.03		0.39	10.47
C10	0.17	1.43		0.21	2.80		0.57	5.17
C11	0.07	0.35			0.58		0.47	1.47
C12+	0.03	0.01			0.03		0.30	0.37
TOTAL	8.88	38.63	4.14	10.27	24.79	11.53	1.75	100.00

FUEL B -- CARB 3 ETHANOL - BY VOLUME% and CARBON NUMBER:

CARBON NUMBER	N-Paraffin	Iso-Paraffin	Olefins	Naphthas	Aromatics	Oxygenate	Un-Classified	Total Per Carbon
C3-			0.00			5.51		5.51
C4	0.92	0.15	0.01					1.08
C5	2.63	7.94	1.52	0.40		0.02		12.51
C6	1.87	12.44	2.34	3.88	0.73			21.25
C7	3.15	8.90	0.65	5.81	6.89			25.40
C8	0.47	10.57	0.27	0.97	8.28		0.01	20.58
C9	0.14	1.57	0.00	0.23	6.49		0.09	8.53
C10	0.04	0.44		0.03	3.04		0.14	3.69
C11	0.02	0.14			0.67		0.20	1.03
C12+	0.03	0.04			0.14		0.22	0.43
TOTAL	9.28	42.17	4.80	11.33	26.23	5.52	0.66	100.00

FUEL C -- CARB 2 NON-OXY - BY VOLUME% and CARBON NUMBER:

CARBON NUMBER	N-Paraffin	Iso-Paraffin	Olefins	Naphthas	Aromatics	Oxygenate	Un-Classified	Total Per Carbon
C3-	0.00							0.00
C4	0.85	0.08						0.93
C5	4.47	12.79	1.16	0.53		0.03		18.97
C6	2.86	16.32	2.78	5.10	0.71	0.01		27.78
C7	1.28	7.11	0.86	2.01	8.41			19.67
C8	0.38	7.94	0.33	1.00	9.77		0.01	19.43
C9	0.13	2.44	0.01	0.28	5.95		0.12	8.93
C10	0.05	0.61		0.07	2.20		0.21	3.13
C11	0.04	0.17			0.43		0.28	0.92
C12+	0.01	0.01			0.06		0.17	0.25
TOTAL	10.07	47.46	5.13	8.98	27.52	0.04	0.79	100.00

Data Collection and Quality Control

Five issues are presented in this section: 1. The correction for ethanol, 2. The technique used to reduce the uncertainty around the steady-state measurement, 3. The definition of stability for the 105°F steady-state measurements, 4. The Quality Control Rig, and 5. Gas Chromatograph (GC) Speciation Procedure

Correction for Ethanol in SHED Measurements - Analyses of SHED samples in the E-65 program at ATL are based on the procedures detailed in the State of California ARB document: "California Non-Methane Organic Gas Test Procedures" as amended August 5, 1999.[7]

A standard Flame Ionization Detector (FID) exhibits different response rates for the different hydrocarbon species occurring in gasoline. These differences are considered to be minor, except for the underreporting on methanol and ethanol. Correction factors for this response rate were initially defined with respect to methanol and carried over to ethanol.

The SHED FID measures Total Hydrocarbon (THC). This reading is corrected with Fuel B by subtracting the ppm of ethanol measured by the gas chromatograph (GC). This corrected THC ppm is used to compute non-ethanol hydrocarbon mass emissions. The non-ethanol mass emissions of Fuel B can be compared to the non-ethanol mass emissions measured with Fuel A and Fuel C.

The ethanol ppm is used to compute the mass of ethanol emissions. The mass of the non-ethanol emissions is added to the mass of the ethanol emissions to arrive at the total emissions for the test.

Three values are reported for ethanol fuels: non-ethanol hydrocarbon emissions, ethanol emissions, and the sum, as shown in Table 6.

Table 6
Permeation Test Results

Rig	Fuel	Week	Date	Test#	NonEtOH (g/hr)	EtOH (g/hr)	NonEtOH + EtOH (g/hr)	Running Average (g/hr)	Note
01	01 Toyota Tacoma								
			03/11/03	Drain and 100% fill fuel A					
	A	7	03/13/03	5086			0.0204	0.0203	
	A	8	03/20/03	5106			0.0094		85°
			03/24/03	Drain and 40% fill fuel A					
	A	D1*	03/25/03	5118			0.253		DHB
	A	D2*	03/26/03	5118			0.229		DHB
			04/09/03	Drain and 100% fill Fuel B					
	B	0	04/10/03	5162	0.0308	0.0053	0.0361		
	B	1	04/17/03	5186	0.0332	0.0248	0.0580		
	B	2	04/23/03	5207	0.0332	0.0232	0.0564		

- D1 and D2 denote Day 1 and Day 2 of the diurnal test. Results are in g/day units.

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[7] CARB website: www.arb.ca.gov/fuels/gasoline/gasoline.htm

Reducing Uncertainty in the Steady-State Measurements - Emission test variation has been an historical concern. Something is measured twice with different values. Which one is right? The concern for variation becomes significant as the measurement levels decrease, perhaps approaching the level of detection. This was a subject of much study during the mid-70s when the exhaust emission standards were "drastically" lowered. (See SAE 770136, "A Treatise on Emission Test Variability", by W. Juneja, et al)

The FIDs used in contemporary evaporative emission testing have a very high level of precision, i.e., the ability to resolve very small concentration differences (not to be confused with "accuracy", a different issue).

The weekly tests were examined using an unusual technique developed by the project Steering Committee to gather the most repeatable data. It is described as follows:

The steady-state testing done at ATL for the E-65 project sampled (measured) the concentration in the SHED every 30 seconds, and with suitable precision to detect a reliable difference, established the emission rate for each half minute. The 30-second measurements were a "grab sample", and 12 of these consecutive samples were averaged to make a six minute average. Ten 6-minute averages were then used to create an hourly permeation rate measurement with a higher level of confidence than simply measuring the concentration at time zero, and then again an hour later.

The procedure was as follows: The measurement SHED was stabilized at the test temperature. The rig was brought from the soak area to the SHED, placed in position, and the door closed and sealed. When the temperature in the SHED had returned to the test temperature and was stable, the 3-hour test started.

The steady-state permeation levels were measured on these rigs as was described in the plan of work, and the project flow charts, for 3 hours at 105°F. The SHED mass was sampled and reported every 30 seconds on the facility's data logger. As mentioned above, 12 readings of the incremental 30-second mass-grams for a 6-minute period were measured and averaged to produce an hourly rate (g/hour).

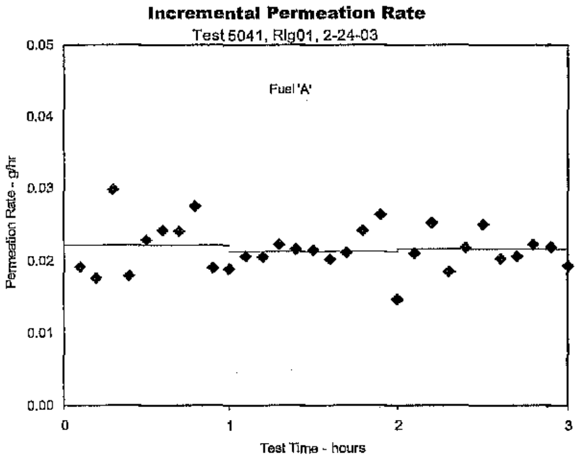

Figure 6

The vertical scale is the permeation hourly rate. Each diamond represents the permeation hourly rate estimate for each 6 minute period. The first hour results shown in Figure 6 were not as stable as desired and were not used further. (See the discussion below regarding the decision to discontinue relying upon the first hour results for determining the weekly steady-state permeation levels.) Highlighted in red were any 6-minute readings that were more than 2 standard deviations from the hourly mean data on the plot. The measurement at 2 hours (red symbol) was outside the 2 standard deviations from the mean level in the analysis. The lab quality supervisor was alerted to a possible problem with the sample or analysis train, and corrective action was taken.

The 10 six minute averages for hour 2 were averaged to establish the average level for hour 2. Ninety % confidence interval estimates (n=10) for the hour 2 mean were calculated using the procedure from Microsoft Excel™. This procedure was repeated for the hour 3 data. Finally, the average of the 20 six minute estimates was used to determine a composite average for hours 2 plus 3.

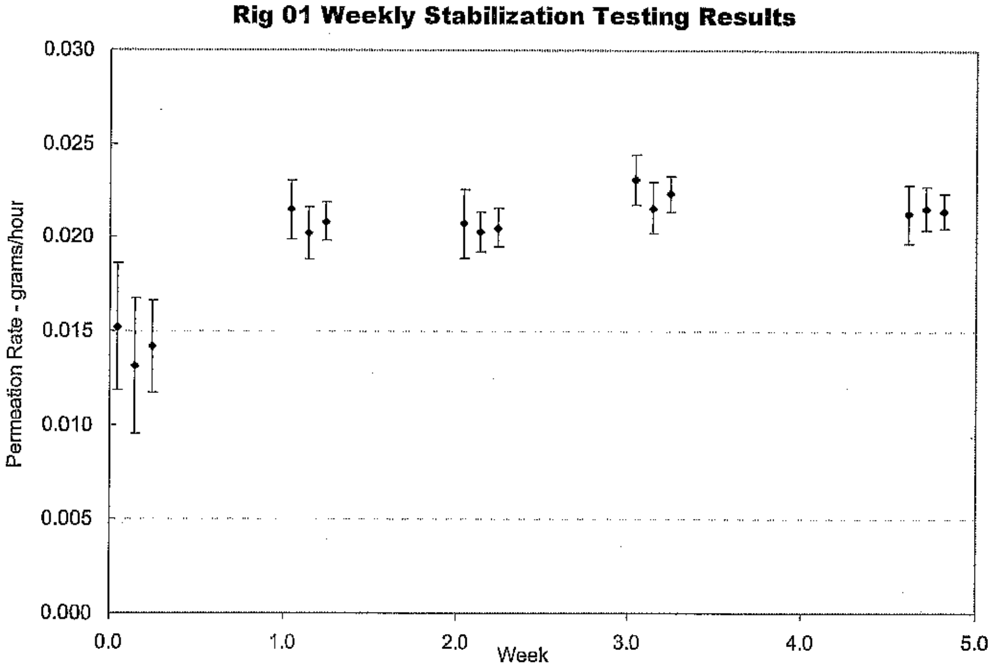

Figure 7

The plot shown in Figure 7 represents the type of data presentation first used for review and approval. For each week there were three estimates. The left most dot and whiskers represented the average and the 90% confidence limits for hour 2. The middle dot and whiskers are the values for hour 3, and the rightmost dot and whiskers are the values for the combined data (n=20) for hours 2 and 3.

It was expected that the data for hour 2 would not be different from hour 3. If a difference was detected, it might be a SHED or rig stability problem. After several months to build confidence, it was decided to discontinue the hour 2-hour 3 comparison, and present only the average value for the 20 measurements made during hours 2 and 3 as the weekly estimate of the permeation rate. The stability of the measurements was continually monitored, and the analysis saved in a lengthy summary called the "Section 3 Analysis."

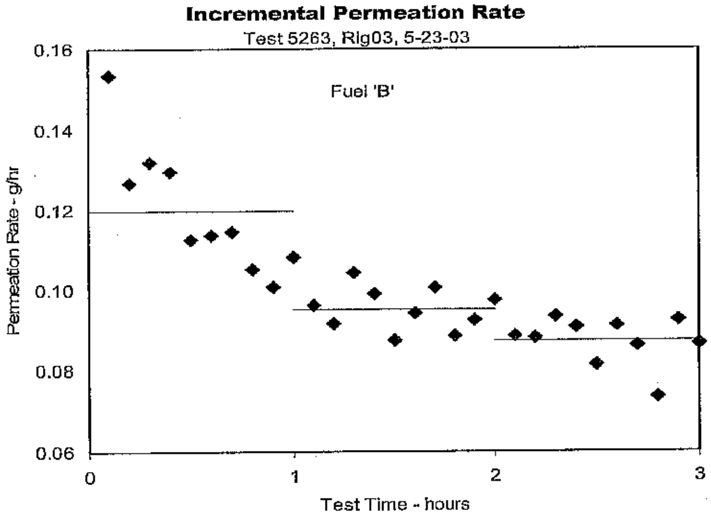

Figure 8

The plot shown in Figure 8 illustrates a condition that was sometimes observed, and led to a decision by the Steering Committee to not use the first hour measurements in the calculation of the weekly average steady-state permeation rate. The vertical scale is the measured emissions rate for each 6-minute sample, expressed in grams/hour. The horizontal scale is the official test period, three hours. An average value for each of the three hours of the test are indicated by the hour long horizontal lines in blue. The first hour average is indicated at 0.12 g/hour.

The trend indicated on the plot in Figure 8 shows a decreasing rate over time. The first hour was higher than later measurements in this example. Hours two and three were relatively stable.

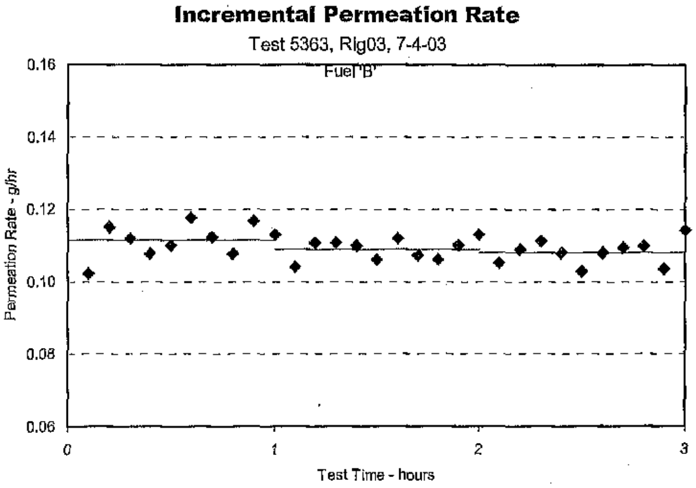

Figure 9

The plot shown in Figure 9 was more typical of the majority of the data. Hours one, two and three had permeation emission rates that were similar – this is what was expected.

The First Hour Anomaly – A Theory Regarding the issue illustrated in Figure 8, the SHED has a heating and cooling system for temperature control. When the SHED was opened to insert the rig, the temperature dropped below the set point. When the door is closed the heating system had to become active to re-establish the temperature. During this re-heating period, there may be some "baking off" of latent HC that had been previously trapped in the fins and crevices of the heat exchanger. This would give a higher initial rate of emissions, gradually returning to some stable value.

Stabilization Technique - Permeation is known to be strongly affected by temperature, and the results of this test program confirm that observation. It was decided to subject the rigs to a constant temperature (105°F), measuring the hourly permeation rate once a week (also at 105°F) until the permeation rate was deemed to be stabilized. The formal criteria for stabilization was a reversal in the 4 test moving average, modified somewhat by the Steering Committee's judgment. An example is offered in Table 7 to explain the concept.

Table 7
Permeation Test Results – Example

2000 Honda Odyssey

Rig	Fuel	Week	Date	Test#	NonEtOH (g/hr)	EtOH (g/hr)	NonEtOH + EtOH (g/hr)	Stdev	Conf.	Running Average	Trend
02	A		05/22/03	Drain and 100% fill fuel A							
		0	05/23/03	5264			0.0817	0.0064	0.0024		
		1	05/30/03	5276			0.0658	0.0040	0.0015		
		2	06/06/03	5293			0.0582	0.0031	0.0011		
		3	06/13/03	5309			0.0608	0.0025	0.0009	0.0666	
		4	06/20/03	5327			0.0668	0.0055	0.0020	0.0629	↓
		5	06/27/03	5345			0.0532	0.0033	0.0012	0.0597	↓
		6	07/04/03	5364			0.0563	0.0032	0.0012	0.0593	↓
		7	07/11/03	5388			0.0513	0.0047	0.0017	0.0569	↓
		8	07/18/03	5411			0.0510	0.0039	0.0014	0.0530	↓
			07/24/03	Drain and 100% fill Fuel A							
		9	07/25/03	5433			0.0595	0.0062	0.0023	0.0545	↑
		10	08/01/03	5456			0.0578	0.0087	0.0032	0.0549	↑

Table 7 was selected from the Microsoft Excel™ file, "Rig Test Summary.xls," which lists the test history for each rig on each fuel. The fuel tank was drained, and filled to 100% of rated capacity on 5/22. The rig was first tested the next day (Week 0), and each week thereafter. The test number is the internal laboratory test identifier. The next 2 columns were used in the later tests to identify the non-EtOH hydrocarbons, and the EtOH measured. The 8th column (NonEtOH + EtOH) is the total permeation rate in grams per hour for that weekly test. The 9th column is the standard deviation calculated from 20 six-minute permeation rate measurements (See the subsection in this report entitled "Reducing Uncertainty in the Steady-State Measurements."). The next column is the 90% confidence interval on the average measurement, given the variation observed in the 20 six-minute observations of the SHED mass increase. The column labeled Running Average is the average of the 4 total permeation values (column 8) reported for the current and the immediately preceding 3 weeks. The final column indicates whether the 4-week running average has decreased or increased.

The average decreased each week from week 4 through week 8 when there was a scheduled fuel change on 7/24. The test on 7/25 replaced a low weekly measurement with a higher one, and the average increased comparable to the previous 4 week value, resulting in a trend reversal. There was concern that the 7/25 measurement was an artifact of the fuel change, and another test was requested. The test on 8/01 verified that the permeation had stabilized, and the rig was authorized for the performance test sequence. This technique is presented graphically in Figure 10.

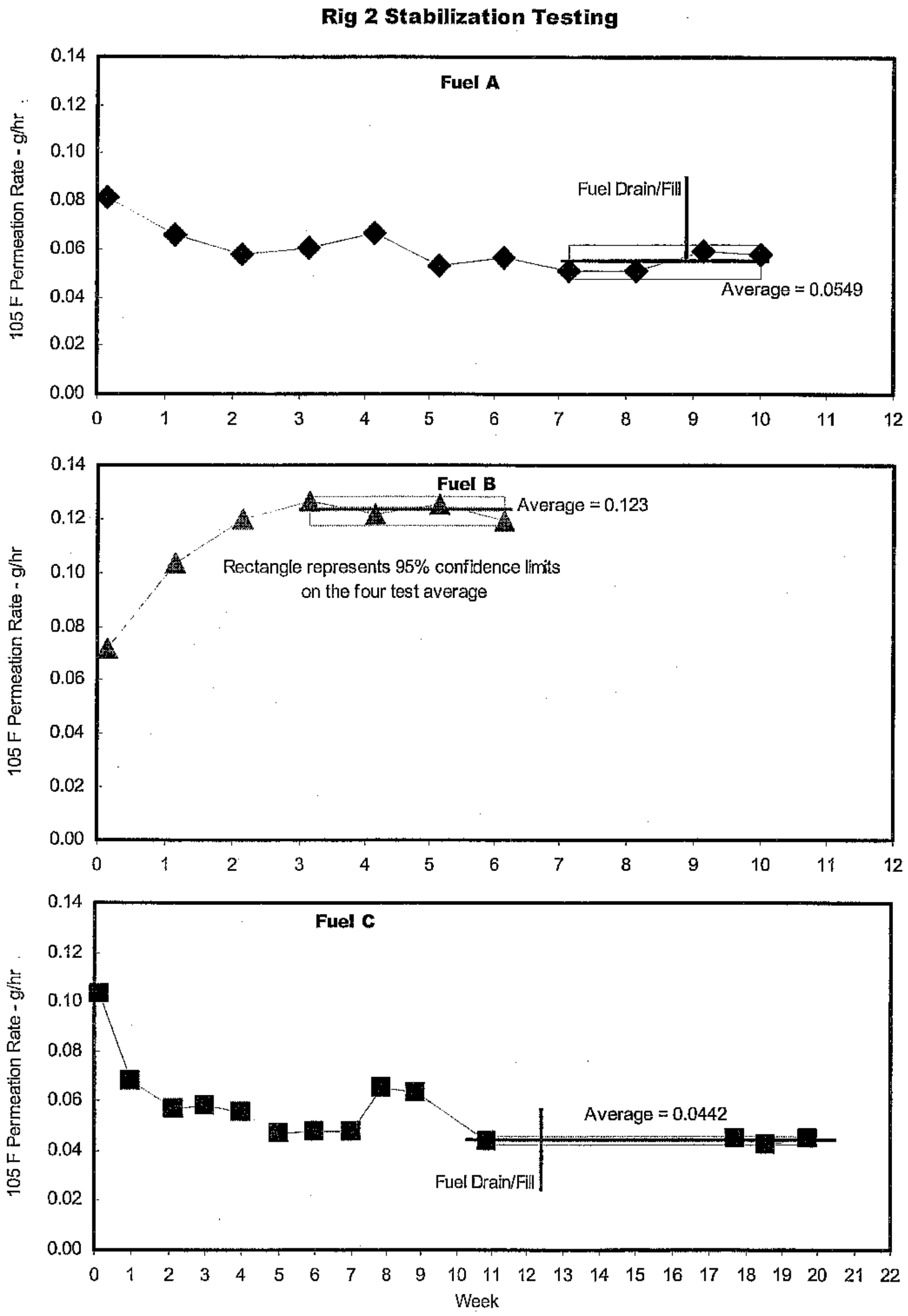
Rig 2 Stabilization Testing
Fuel A
Fuel Drain/Fill
Average = 0.0549
Fuel B
Average = 0.123
Rectangle represents 95% confidence limits on the four test average
Fuel C
Average = 0.0442
Fuel Drain/Fill
105 F Permeation Rate - g/hr
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Week

Figure 10

The Quality Control Rig - Previous experience had proved the value of a "repeatable" emission source as a quality check on the emission measurement system. Early in the project a "quality control rig" was fabricated using a 23-gallon capacity non-metallic fuel tank to perform this service. The fuel tank used was the same make and model as the one on Rig 6, the 1993 Chevrolet Caprice. The large capacity meant it would hold a lot of fuel, and have less sensitivity to "weathering" of the fuel, since periodic fuel changes were not planned.

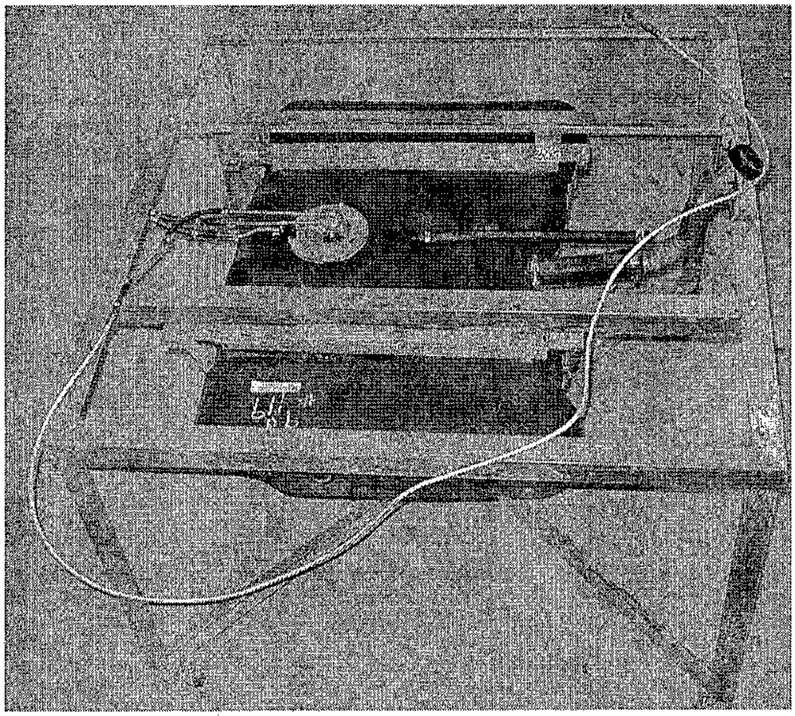

Figure 11. The QC Rig

A photo of the QC Rig appears in Figure 11. It consists of a HDPE 23-gallon fuel tank and fill pipe assembly, with short stub hoses on the fuel and vapor vent lines. The vapor space of the tank is vented outside the SHED during the permeation test measurement, as was done on the test rigs.

Figure 12 shows the weekly permeation rate measurements made on the QC Rig. The horizontal scale is the individual weekly measurements. Fifty-eight (58) weeks of the latest data are shown. The vertical scale (note the expanded scale used) is the hourly rate, roughly 0.3 g/hour. The dot represents the average value, and the "whiskers" show the 90% confidence estimate on the average value, based on the 20 six-minute values used to create the average value. A trend line was fitted to the plot using the Microsoft Excel™ routines. The fuel was not changed during this interval, and some weathering occurred. The level dropped about 0.05 grams per hour over the 58-week period, and this was considered an acceptable amount for our purposes.

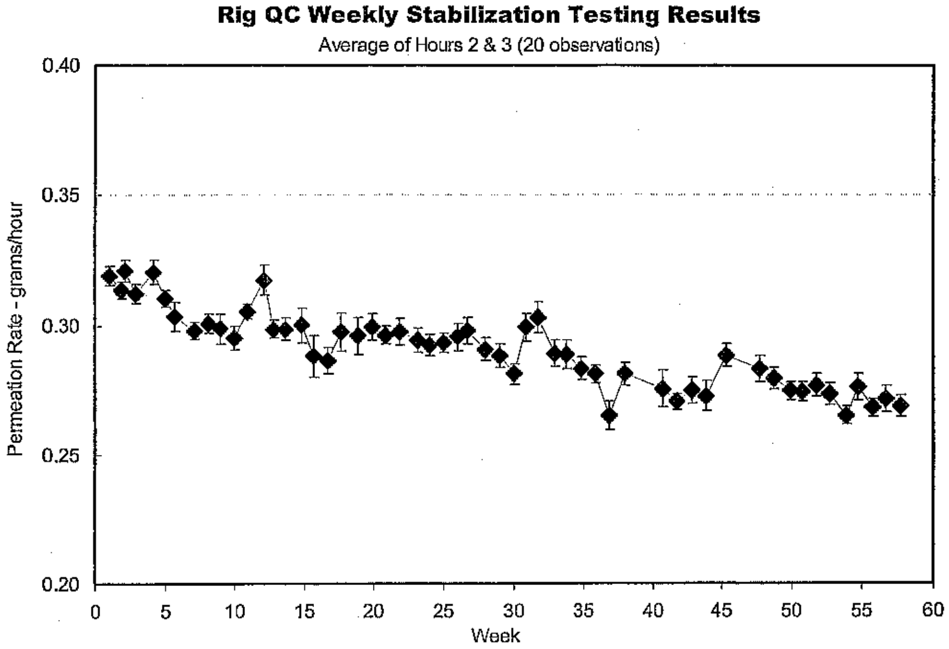

Figure 12

The 4 week running averages of the weekly permeation data for the QC Rig are shown in Figure 13.

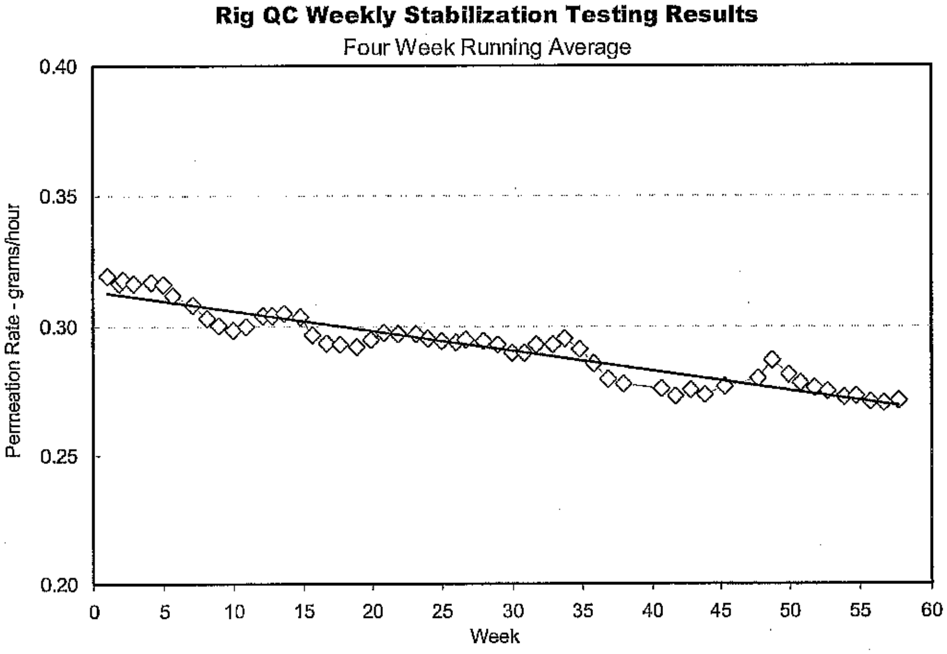

Figure 13

Gas Chromatograph (GC) Speciation Procedure - The testing laboratory (ATL) had developed a hydrocarbon speciation method that is functionally equivalent to, but possibly more efficient than, the dual-GC Auto-Oil Air Quality Improvement Research Program (AQIRP) method (no third column for benzene and toluene separations). This method has been used at ATL for much of its speciation. Instrumentation demands are simplified, and overall analysis time is shortened, yet high resolution and sensitivity are still achieved. In this single-GC method, all components are separated using one column type and temperature program. Analysis time for a cycle is 65 minutes. Each exhaust or evaporative gas sample is simultaneously injected (using a single sampling from the bag) into identical columns present in the dual column GC. Column A contains a 85 μl sample loop (splitless injection) that provides an injection volume that is small enough to allow resolution of the C_1 through C_4 hydrocarbons while large enough to retain the highest sensitivity possible. Column B receives a 1000 μl splitless injection, providing higher sensitivity for components eluting after isobutane. In both cases, the sample loop is controlled at column head pressure giving ambient pressure sample sizes of 195 μl and 2000 μl for the small and large injections, respectively. Quantitative comparison of three overlap components (butane, isopentane, and pentane) provides a quality control measure. Data from column A is used to detect and quantitate the 12 earliest eluting hydrocarbons (corresponding to the first 15 hydrocarbons listed in the SAE 930142 Hydrocarbon Speciation Library, minus t-2-butene, n-butane, and 2,2-dimethylpropane) with detection limits of 15-25 ppb C, corresponding to 0.2-0.3 mg/mi hydrocarbon for FTP stages 1 and 3, and 0.3-0.5 mg/mi for FTP stage 2. Data from column B gives detection limits of 0.017-0.04 mg/mi HC for components eluting after isopentane (18th in elution order). The components eluting between the 9th and 18th in elution order have detection limits ranging between the levels listed above for each column. In previous work which applied this analytical approach, detection limits were determined to be between 0.02 and 0.06 mg/mi for 1,3-butadiene and benzene. These detection limits can be compared to detection limits of 0.1 mg/mi (FTP composite) using the SAE 930142/AQIRP method. Benzene is sufficiently resolved from 1-methylcyclopentene using this method with no significant interferences; this is an advantage of ATL's method over the AQIRP method, which does not resolve this important pair in the C_4-C_{12} method. ATL's chromatographic conditions have been optimized to resolve these two species to a ratio of about 1:20, 1-methylcyclopentene:benzene. Thus, ATL's method gives an expected accuracy for benzene of 95% or greater.

Results

The original test program, (105°F stabilization, 85°F steady-state test, and a 2-day 65-105-65°F diurnal test) was completed in late May of 2004. Hydrocarbon speciation was specified in the original task and the results were later augmented with the inclusion of maximum incremental ozone reactivity (MIR) values drawn from the literature. Two additional assignments (replicate diurnal tests on Fuel C, and a sensitivity test with reduced fill on the non-metallic tanks were completed in July of 2004.

The results from these test components (on the three test fuels) are presented in the following order:

- Stabilization at 105°F
- Diurnal Measurements
- Speciation of the Diurnal SHED Vapors
- Reactivity Calculations
- The Increase in Non-Ethanol Hydrocarbon with Fuel B
- Steady-state Test Results - 105°F and 85°F
- Estimate of Experimental Variation
- Fill Level Comparison -- 100% vs. 20% Preconditioning on Fuel C

Stabilization at 105°F - Figure 14 on the next two pages displays the stabilization results for all three test fuels on all ten rigs. As a reminder, Fuel A is the MTBE blend, Fuel B is the ethanol blend and Fuel C is the non-oxygenated blend

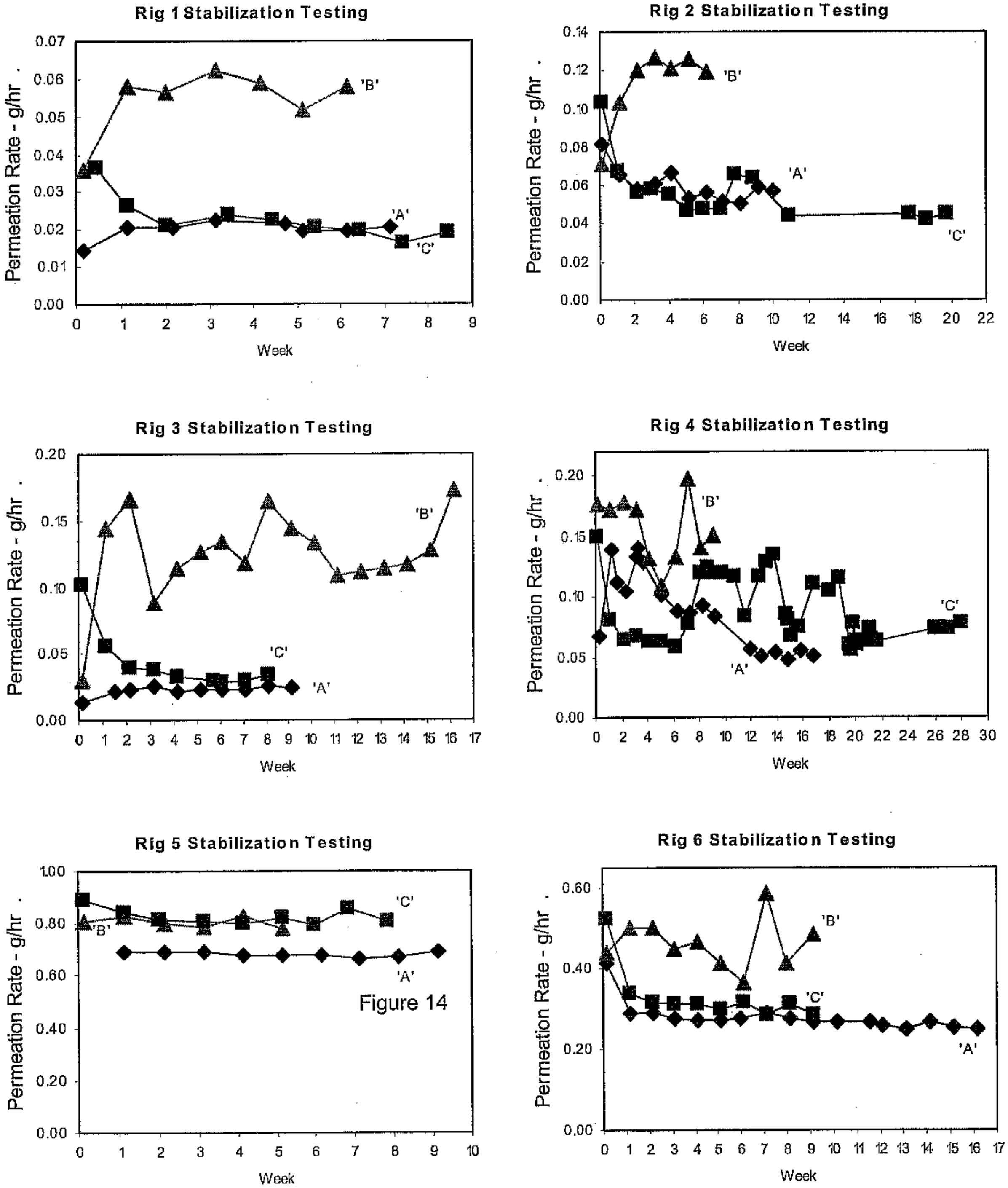

Figure 14

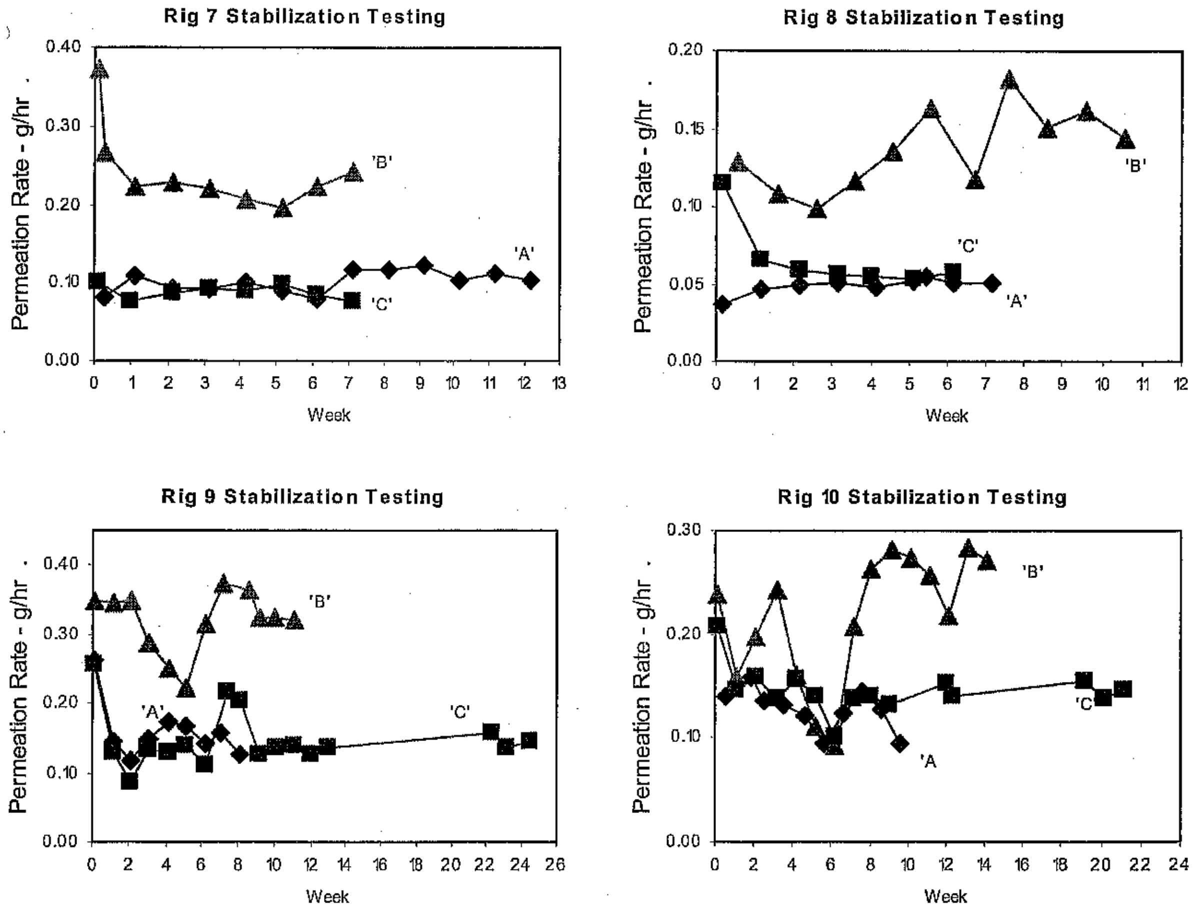

Figure 14 (Cont.)

Diurnal Measurements – Table 8 shows the average diurnal permeation results for the ten rigs on the three test fuels after stabilization at 105°F. All values are the average of days 1 and 2, and where multiple valid tests are available, all the data were used.

Table 8
Average Diurnal Values

			Average Emissions - g/day		
Rig	Vehicle	Tank	Fuel A	Fuel B	Fuel C
1	2001 Toyota Tacoma	15.8 gal - Metal	0.24	0.76	0.22
2	2000 Honda Odyssey	20.0 gal - Plastic	0.64	1.43	0.58
3	1999 Toyota Corolla	13.2 gal - Metal	0.29	1.37	0.33
4	1997 Chrysler Town & Country	20.0 gal - Plastic	0.63	2.25	1.13
5	1995 Ford Ranger	16.5 gal - Plastic	9.20	11.65	11.75
6	1993 Chevrolet Caprice Classic	23.0 gal - Plastic	4.55	4.89	3.55
7	1991 Honda Accord LX	17.0 gal - Metal	1.24	2.25	1.91
8	1989 Ford Taurus GL	16.0 gal - Metal	0.96	2.63	0.82
9	1985 Nissan Sentra	13.2 gal - Metal	1.96	4.67	1.77
10	1978 Olds Cutlass Supreme	18.1 gal - Metal	1.92	3.74	2.44
		Average	2.16	3.56	2.45

The behavior of Rig 5 on Fuel C is anomalous in that it is the only rig in which the permeation emissions on Fuel C were similar to those on Fuel B. Exhaustive checks of Rig 5's fuel system were performed, but no cause for the anomalous behavior could be identified. The data were considered valid and included in subsequent analyses.

Plots of the diurnal permeation results are shown in Figure 15. The horizontal axis is the model year of the test rigs. The vertical lines are the model year breaks for the deciles in the in-use California fleet. The vertical scale is the test results measured in the SHED in grams per day.

Looking at the left most test results (1978 – Rig 10), the green bar represents the average diurnal on Fuel A (1.92 g/day). The red bar is the representation of the Fuel B results (3.74 g/day). The blue bar is the Fuel C test results (2.44 g/day). Each rig is represented by a similar set of three colored bars.

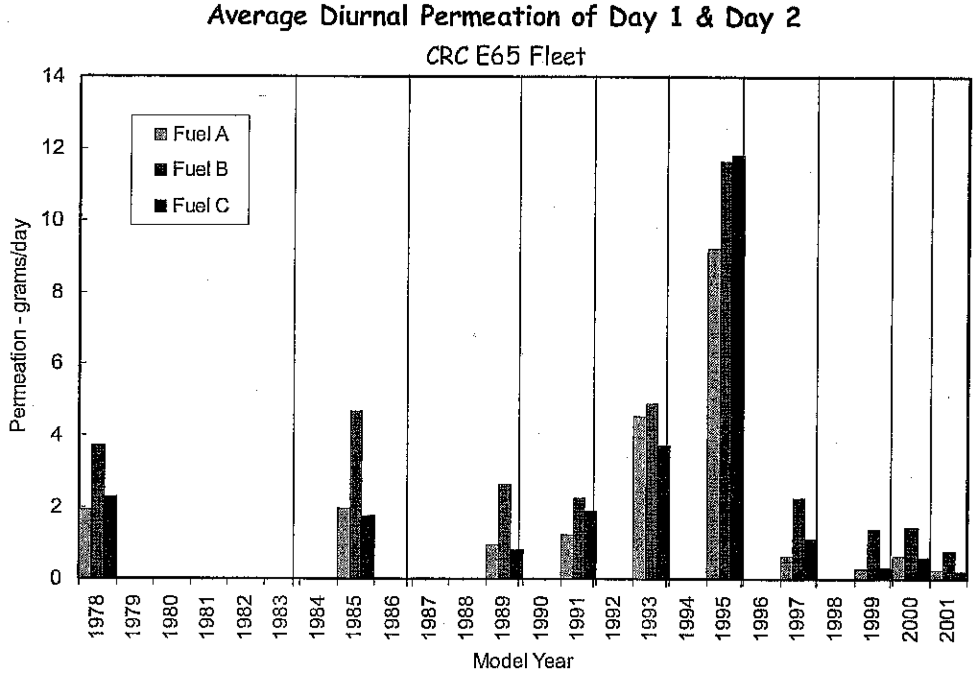

Figure 15

Speciation Results (Diurnal) - Each rig was tested for at least two days using the California diurnal test procedure, on each of the three test fuels. A sample of the enclosure's ambient HC concentration was collected from the VT-SHED at the start and the end of each day in a Tedlar™ bag and later analyzed using a Varian™ chromatograph. The net mass change in the enclosure was computed for each of the two diurnal days.

An example of the speciation results for Rig 1 – Fuel A, days 1 & 2 is shown in Table 9. The complete speciation results are available on the companion CD ROM. Please note that the 48 hour results are the net cumulative increase for the two days. Results for day 2 can be calculated by subtracting the 24 hour (day 1) mass from the 48 hour results (day 1 + 2).

Rig: 01a
Test#: 5118

Table 9.
Speciation Results

Detailed Hydrocarbon Speciation Results

			24 Hour				48 Hour			
			Net mass	Net conc.	% total		Net mass	Net conc.	% total	
	Species Name	CAS #	(mg)	(ppmC)	(mg)	(ppmC)	(mg)	(ppmC)	(mg)	(ppmC)
1	Methane	00074-82-8	0.549	0.014	0%	0%	1.618	0.044	0%	0%
2	Ethylene	00074-85-1	0.000	0.000	0%	0%	0.000	0.000	0%	0%
3	Acetylene (Ethyne)	00074-86-2	0.000	0.000	0%	0%	0.000	0.000	0%	0%
4	Ethane	00074-84-0	0.000	0.000	0%	0%	0.000	0.000	0%	0%
5	Propene	00115-07-1	0.000	0.000	0%	0%	0.000	0.000	0%	0%
6	Propane	00074-98-6	0.000	0.000	0%	0%	1.396	0.043	0%	0%
7	Allene (Propadiene)	00463-49-0	0.000	0.000	0%	0%	0.000	0.000	0%	0%
8	Propyne	00074-99-7	0.000	0.000	0%	0%	0.000	0.000	0%	0%
9	2-Methylpropane	00075-28-5	0.694	0.022	0%	0%	1.382	0.043	0%	0%
10.1	2-Methylpropene	00115-11-7	0.246	0.008	0%	0%	0.418	0.013	0%	0%
10.2	1-Butene	00106-98-9	0.130	0.004	0%	0%	0.222	0.007	0%	0%
11	1,3-Butadiene	00106-99-0	0.000	0.000	0%	0%	0.000	0.000	0%	0%
12	n-Butane	00106-97-8	6.863	0.213	3%	3%	13.262	0.412	3%	3%
13	2,2-Dimethylpropane	00463-82-1	0.000	0.000	0%	0%	0.000	0.000	0%	0%
14	t-2-Butene	00624-64-6	0.432	0.014	0%	0%	3.039	0.098	1%	1%
15	1-Butyne	00107-00-6	0.682	0.023	0%	0%	0.000	0.000	0%	0%
16	c-2-Butene	00590-18-1	0.180	0.006	0%	0%	0.346	0.011	0%	0%
17	3-Methyl-1-butene	00563-45-1	0.639	0.021	0%	0%	1.746	0.056	0%	0%
18	2-Methylbutane (Isopentane)	00078-78-4	32.940	1.031	14%	14%	64.662	2.024	14%	14%
19.1	1-Pentene	00109-67-1	0.217	0.007	0%	0%	0.870	0.029	0%	0%
19.2	2-Butyne	00503-17-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
20	2-Methyl-1-butene	00563-46-2	0.672	0.022	0%	0%	1.533	0.049	0%	0%
21	n-Pentane	00109-66-0	10.984	0.344	5%	5%	21.906	0.686	5%	5%
22	2-Methyl-1,3-butadiene	00078-79-5	0.000	0.000	0%	0%	0.131	0.004	0%	0%
23	t-2-Pentene	00646-04-8	1.558	0.050	1%	1%	3.084	0.099	1%	1%
24	3,3-Dimethyl-1-butene	00558-37-2	0.000	0.000	0%	0%	0.000	0.000	0%	0%
25	c-2-Pentene	00627-20-3	0.637	0.021	0%	0%	1.422	0.046	0%	0%
26	2-Methyl-2-butene	00513-35-9	2.808	0.090	1%	1%	5.560	0.179	1%	1%
27	Unknown #1		0.000	0.000	0%	0%	0.000	0.000	0%	0%
28	Cyclopentadiene	00542-92-7	0.000	0.000	0%	0%	0.000	0.000	0%	0%
29	2,2-Dimethylbutane	00075-83-2	1.199	0.038	0%	0%	2.400	0.075	1%	1%
30	Cyclopentene	00142-29-0	0.446	0.015	0%	0%	0.764	0.025	0%	0%
31.1	4-methyl-1-pentene	00691-37-2	0.000	0.000	0%	0%	0.329	0.011	0%	0%
31.2	3-methyl-1-pentene	00760-20-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
32	Cyclopentane	00287-92-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
33	MTBE	01634-04-4	33.333	0.843	14%	11%	65.317	1.652	14%	11%
34	2,3-Dimethylbutane	00079-29-8	4.089	0.116	2%	2%	8.012	0.227	2%	2%
34.1	2,3dimethyl-1-butene	00563-78-0	0.000	0.000	0%	0%	0.000	0.000	0%	0%
35	Unknown #2		0.000	0.000	0%	0%	0.000	0.000	0%	0%
36.1	2-MePentane	00107-83-5	9.176	0.289	4%	4%	17.942	0.565	4%	4%
36.2	4-Me-c-2-Pentene	00691-38-3	0.049	0.002	0%	0%	0.097	0.003	0%	0%
37	4-Methyl-t-2-pentene	00674-76-0	0.000	0.000	0%	0%	0.000	0.000	0%	0%
38	3-Methylpentane	00096-14-0	5.285	0.166	2%	2%	10.294	0.324	2%	2%
39.1	2-Methyl-1-pentene	00763-29-1	0.335	0.011	0%	0%	0.581	0.019	0%	0%
39.2	1-Hexene	00592-41-6	0.147	0.005	0%	0%	0.256	0.008	0%	0%
40	n-Hexane	00110-54-3	5.789	0.182	2%	2%	11.173	0.352	2%	2%
41.1	t-3-Hexene	13269-52-8	0.000	0.000	0%	0%	0.000	0.000	0%	0%
41.2	c-3-Hexene	07642-09-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
42	t-2-Hexene	04050-45-7	0.465	0.015	0%	0%	0.739	0.024	0%	0%
43	3-Methyl-t-2-pentene	00616-12-6	0.552	0.018	0%	0%	0.892	0.029	0%	0%
44	2-Methyl-2-pentene	00625-27-4	0.585	0.019	0%	0%	0.783	0.025	0%	0%

Rig: 01a
Test#: 5118

Table 9 (cont).
Speciation Results

Detailed Hydrocarbon Speciation Results

			24 Hour				48 Hour			
			Net mass	Net conc.	% total		Net mass	Net conc.	% total	
	Species Name	CAS #	(mg)	(ppmC)	(mg)	(ppmC)	(mg)	(ppmC)	(mg)	(ppmC)
45.1	c-2-Hexene	07688-21-3	0.232	0.008	0%	0%	0.314	0.011	0%	0%
45.2	3-MeCyclopentene	01120-62-3	0.122	0.004	0%	0%	0.166	0.005	0%	0%
46	ETBE	00637-92-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
47	3-Methyl-c-2-pentene	00922-62-3	0.695	0.022	0%	0%	0.976	0.031	0%	0%
48	2,2-Dimethylpentane	00590-35-2	0.457	0.014	0%	0%	0.486	0.015	0%	0%
49	Methylcyclopentane	00096-37-7	5.738	0.185	2%	2%	10.877	0.350	2%	2%
50	2,4-Dimethylpentane	00108-08-7	1.321	0.042	1%	1%	2.379	0.075	1%	1%
51	2,2,3-Trimethylbutane	00464-06-2	0.408	0.013	0%	0%	0.454	0.014	0%	0%
52	1-Methylcyclopentene	00693-89-0	0.239	0.008	0%	0%	0.229	0.008	0%	0%
53	Benzene	00071-43-2	6.424	0.223	3%	3%	11.928	0.414	3%	3%
54	3,3-Dimethylpentane	00562-49-2	0.232	0.007	0%	0%	0.303	0.010	0%	0%
55	3-Me-1-Hexene	03404-61-3	0.269	0.009	0%	0%	0.314	0.010	0%	0%
56	Cyclohexane	00110-82-7	2.459	0.079	1%	1%	4.606	0.148	1%	1%
57	2-Methylhexane	00591-76-4	2.488	0.078	1%	1%	4.567	0.144	1%	1%
58	2,3-Dimethylpentane	00565-59-3	1.456	0.046	1%	1%	2.694	0.085	1%	1%
59.1	Cyclohexene	00110-83-8	0.000	0.000	0%	0%	0.000	0.000	0%	0%
59.2	3-Methylhexane	00589-34-4	2.495	0.079	1%	1%	4.793	0.151	1%	1%
60	Unknown #3		0.196	0.006	0%	0%	0.390	0.013	0%	0%
61	c-1,3-Dimethylcyclopentane	02532-58-3	0.813	0.026	0%	0%	1.620	0.052	0%	0%
62	t-1,2-Dimethylcyclopentane	00822-50-4	1.146	0.037	0%	0%	2.110	0.068	0%	0%
63	2,2,4-TriMePentane (IsoOctane)	00540-84-1	3.976	0.126	2%	2%	7.534	0.238	2%	2%
64	1-Heptene	00592-76-7	0.000	0.000	0%	0%	0.254	0.008	0%	0%
65	t-3-Heptene	14686-14-7	0.000	0.000	0%	0%	0.231	0.007	0%	0%
66	n-Heptane	00142-82-5	1.771	0.056	1%	1%	3.317	0.105	1%	1%
67.1	2-Methyl-2-Hexene	02738-19-4	0.395	0.013	0%	0%	0.982	0.032	0%	0%
67.2	c-3-Heptene	07642-10-6	0.000	0.000	0%	0%	0.000	0.000	0%	0%
68.1	3-Me-t-3-Hexene	03899-36-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
68.2	t-2-Heptene	14686-13-6	0.000	0.000	0%	0%	0.000	0.000	0%	0%
69	3-Ethyl-c-2-Pentene	00816-79-5	0.000	0.000	0%	0%	0.531	0.017	0%	0%
70.1	244Trimethyl1pentene	00107-39-1	0.000	0.000	0%	0%	0.000	0.000	0%	0%
70.2	23-diMe-2-pentene	10574-37-5	0.151	0.005	0%	0%	0.394	0.013	0%	0%
71	c-2-Heptene	06443-92-1	0.244	0.008	0%	0%	1.033	0.033	0%	0%
72	Unknown #4		0.000	0.000	0%	0%	0.000	0.000	0%	0%
73	2,2-DiMeHexane	00590-73-8	0.000	0.000	0%	0%	0.000	0.000	0%	0%
74	Methylcyclohexane	00108-87-2	1.614	0.052	1%	1%	4.048	0.130	1%	1%
75	2,4,4-Trimethyl-2-Pentene	00107-40-4	0.207	0.007	0%	0%	0.204	0.007	0%	0%
76.1	2,5-DiMeHexane	00592-13-2	0.208	0.007	0%	0%	0.565	0.019	0%	0%
76.2	EtCyPentane	01640-89-7	0.200	0.006	0%	0%	0.542	0.016	0%	0%
77	2,4-Dimethylhexane	00589-43-5	1.093	0.035	0%	0%	2.166	0.069	0%	0%
78	3,3-Dimethylhexane	00563-16-6	0.300	0.009	0%	0%	0.673	0.021	0%	0%
79	2,3,4-Trimethylpentane	00565-75-3	1.140	0.036	0%	0%	2.312	0.073	0%	0%
80	2,3,3-Trimethylpentane	00560-21-4	0.000	0.000	0%	0%	0.000	0.000	0%	0%
81	Toluene	00108-88-3	47.503	1.630	20%	21%	91.075	3.125	19%	21%
82.1	2,3-dimethylhexane	00584-94-1	0.000	0.000	0%	0%	0.000	0.000	0%	0%
82.2	2-Me-3-Et-pentane	00609-26-7	0.481	0.015	0%	0%	0.680	0.022	0%	0%
83	2-Methylheptane	00592-27-8	0.737	0.023	0%	0%	1.130	0.036	0%	0%
84.1	1-MeCyHexene	00591-49-1	0.000	0.000	0%	0%	0.000	0.000	0%	0%
84.2	4-MeHeptane	00589-53-7	0.411	0.013	0%	0%	0.522	0.017	0%	0%
85	Unknown #5		0.000	0.000	0%	0%	0.238	0.008	0%	0%
86	3-Methylheptane	00589-81-1	0.554	0.018	0%	0%	1.256	0.040	0%	0%
87	1c-2t-3-TriMeCyPentane	15890-40-1	0.000	0.000	0%	0%	0.000	0.000	0%	0%

Rig: 01a
Test#: 5118

Table 9 (cont).
Speciation Results

Detailed Hydrocarbon Speciation Results

			24 Hour				48 Hour			
			Net mass	Net conc.	% total		Net mass	Net conc.	% total	
	Species Name	CAS #	(mg)	(ppmC)	(mg)	(ppmC)	(mg)	(ppmC)	(mg)	(ppmC)
88	c-1,3-Dimethylcyclohexane	00638-04-0	0.452	0.015	0%	0%	0.729	0.023	0%	0%
89	t-1,4-Dimethylcyclohexane	02207-04-7	0.000	0.000	0%	0%	0.297	0.010	0%	0%
90	*2,2,5-Trimethylhexane*	*03522-94-9*	*0.547*	*0.017*	*0%*	*0%*	*0.720*	*0.023*	*0%*	*0%*
91	1-Octene	00111-66-0	0.000	0.000	0%	0%	0.000	0.000	0%	0%
92	1,1-Dimethylcyclohexane	00590-66-9	0.283	0.009	0%	0%	0.425	0.014	0%	0%
93	Unknown #6		0.114	0.004	0%	0%	0.310	0.010	0%	0%
94	t-4-Octene	14850-23-8	0.000	0.000	0%	0%	0.216	0.007	0%	0%
95	Unknown #7		0.000	0.000	0%	0%	0.000	0.000	0%	0%
96	n-Octane	00111-65-9	0.391	0.012	0%	0%	0.942	0.030	0%	0%
97.1	t-2-Octene	13389-42-9	0.000	0.000	0%	0%	0.000	0.000	0%	0%
97.2	t-1,2-DiMeCyHexane	06876-23-9	0.000	0.000	0%	0%	0.000	0.000	0%	0%
98.1	t-1,3	02207-03-6	0.381	0.012	0%	0%	0.591	0.019	0%	0%
98.2	c-1,4-DiMeCyHexane	00624-29-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
99	c-2-Octene	07642-04-8	0.000	0.000	0%	0%	0.000	0.000	0%	0%
100	2,3,5-Trimethylhexane	01069-53-0	0.301	0.010	0%	0%	0.561	0.018	0%	0%
101	2,4-Dimethylheptane	02213-23-2	0.192	0.006	0%	0%	0.192	0.006	0%	0%
102	Unknown #8		0.159	0.005	0%	0%	0.124	0.004	0%	0%
103	c-1,2-Dimethylcyclohexane	02207-01-4	0.000	0.000	0%	0%	0.000	0.000	0%	0%
104	Ethylcyclohexane	01678-91-7	0.719	0.023	0%	0%	0.892	0.029	0%	0%
105	3,5-Dimethylheptane	00926-82-9	0.000	0.000	0%	0%	0.000	0.000	0%	0%
106	Unknown #9		0.000	0.000	0%	0%	0.183	0.006	0%	0%
107	*Unknown #10*		*0.000*	*0.000*	*0%*	*0%*	*0.327*	*0.011*	*0%*	*0%*
108	Unknown #11		0.000	0.000	0%	0%	0.000	0.000	0%	0%
109	Ethylbenzene	00100-41-4	3.575	0.122	1%	2%	6.813	0.232	1%	2%
110.1	2,3-DiMeHeptane	03074-71-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
110.2	2-MeOctane	03221-61-2	0.000	0.000	0%	0%	0.000	0.000	0%	0%
111.1	m-Xylene	00108-38-3	11.739	0.399	5%	5%	22.337	0.759	5%	5%
111.2	p-Xylene	00106-42-3	3.600	0.123	1%	2%	6.850	0.234	1%	2%
112	4-Methyloctane	02216-34-4	0.542	0.017	0%	0%	0.622	0.020	0%	0%
113	3-Methyloctane	02216-33-3	0.310	0.010	0%	0%	0.311	0.010	0%	0%
114	Unknown #12		0.000	0.000	0%	0%	0.000	0.000	0%	0%
115	Styrene	00100-42-5	0.061	0.002	0%	0%	0.209	0.007	0%	0%
116	Unknown #13		0.000	0.000	0%	0%	0.000	0.000	0%	0%
117	ortho-Xylene	00095-47-6	1.690	0.057	1%	1%	3.821	0.130	1%	1%
118	1-Nonene	00124-11-8	0.000	0.000	0%	0%	0.000	0.000	0%	0%
119	c- & t-4-Nonene	02198-23-4	0.000	0.000	0%	0%	0.000	0.000	0%	0%
120	n-Nonane	00111-84-2	0.000	0.000	0%	0%	0.000	0.000	0%	0%
121	t-2-Nonene	06434-78-2	0.000	0.000	0%	0%	0.000	0.000	0%	0%
122	Isopropylbenzene (Cumene)	00098-82-8	0.000	0.000	0%	0%	0.228	0.008	0%	0%
123	2,2-Dimethyloctane	15869-87-1	0.000	0.000	0%	0%	0.000	0.000	0%	0%
124	*Unknown #14*		*0.000*	*0.000*	*0%*	*0%*	*0.000*	*0.000*	*0%*	*0%*
125.1	2,4-DiMeOctane	04032-94-4	0.000	0.000	0%	0%	0.000	0.000	0%	0%
125.2	AlBenz	00300-57-2	0.000	0.000	0%	0%	0.000	0.000	0%	0%
125.3	PrCyHexane	01678-92-8	0.000	0.000	0%	0%	0.000	0.000	0%	0%
126	*Unknown #15*		*0.000*	*0.000*	*0%*	*0%*	*0.000*	*0.000*	*0%*	*0%*
127	n-Propylbenzene	00103-65-1	0.534	0.018	0%	0%	1.083	0.037	0%	0%
128	1-Methyl-3-Ethylbenzene	00620-14-4	1.853	0.063	1%	1%	3.304	0.112	1%	1%
129	1-Methyl-4-Ethylbenzene	00622-96-8	0.908	0.031	0%	0%	1.518	0.051	0%	0%
130	1,3,5-Trimethylbenzene	00108-67-8	1.144	0.039	0%	1%	1.333	0.045	0%	0%
131	Unknown #16		0.000	0.000	0%	0%	0.000	0.000	0%	0%
132	Unknown #17		0.000	0.000	0%	0%	0.000	0.000	0%	0%

Rig: 01a
Test#: 5118

Table 9 (cont).
Speciation Results

Detailed Hydrocarbon Speciation Results

			24 Hour				48 Hour			
			Net mass	Net conc.	% total		Net mass	Net conc.	% total	
	Species Name	CAS #	(mg)	(ppmC)	(mg)	(ppmC)	(mg)	(ppmC)	(mg)	(ppmC)
133	1-Ethyl-2-Methylbenzene	00611-14-3	0.513	0.017	0%	0%	1.150	0.039	0%	0%
134	3-Methylnonane		0.000	0.000	0%	0%	0.000	0.000	0%	0%
135.1	1,2,4-TriMeBenz	00095-63-6	0.000	0.000	0%	0%	0.000	0.000	0%	0%
135.2	t-Butylbenzene	00098-06-6	0.000	0.000	0%	0%	0.000	0.000	0%	0%
136	n-Decane	00124-18-5	0.000	0.000	0%	0%	0.000	0.000	0%	0%
137	Isobutylbenzene	00538-93-2	0.000	0.000	0%	0%	0.000	0.000	0%	0%
138	sec-Butylbenzene	00135-98-8	0.000	0.000	0%	0%	0.000	0.000	0%	0%
139	1-Methyl-4-Isobutylbenzene	05161-04-6	0.622	0.021	0%	0%	0.000	0.000	0%	0%
140	1,2,3-Trimethylbenzene	00526-73-8	0.000	0.000	0%	0%	0.842	0.028	0%	0%
141	4-Isopropyltoluene (p-Cymene)	00099-87-6	0.000	0.000	0%	0%	0.000	0.000	0%	0%
142	Indan	00496-11-7	0.403	0.014	0%	0%	0.847	0.029	0%	0%
143	1,3-Diethylbenzene	00141-93-5	0.278	0.009	0%	0%	0.000	0.000	0%	0%
144	1-Methyl-3-Propylbenzene	01074-43-7	0.000	0.000	0%	0%	0.471	0.016	0%	0%
145	1,4-Diethylbenzene	00105-05-5	0.449	0.015	0%	0%	0.664	0.022	0%	0%
146	1,2-Diethylbenzene	00135-01-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
147	n-Butylbenzene	00104-51-8	0.000	0.000	0%	0%	0.000	0.000	0%	0%
148	1-Methyl-2-Propylbenzene	01074-17-5	0.000	0.000	0%	0%	0.000	0.000	0%	0%
149	1,4-Dimethyl-2-Ethylbenzene	01758-88-9	0.000	0.000	0%	0%	0.292	0.010	0%	0%
150	1,3-Dimethyl-4-Ethylbenzene	00874-41-9	0.000	0.000	0%	0%	0.267	0.009	0%	0%
151	1,2-Dimethyl-4-Ethylbenzene	00934-80-5	0.190	0.006	0%	0%	0.195	0.007	0%	0%
152	1,3-Dimethyl-2-Ethylbenzene	02870-04-4	0.000	0.000	0%	0%	0.000	0.000	0%	0%
153	1-Undecene	00821-95-4	0.000	0.000	0%	0%	0.000	0.000	0%	0%
154	n-Undecane	01120-21-4	0.000	0.000	0%	0%	0.000	0.000	0%	0%
155	Unknown #18		0.000	0.000	0%	0%	0.000	0.000	0%	0%
156	Unknown #19		0.000	0.000	0%	0%	0.000	0.000	0%	0%
157	1,2,4,5-Tetramethylbenzene	00095-93-2	0.000	0.000	0%	0%	0.000	0.000	0%	0%
158	1,2,3,5-Tetramethylbenzene	00527-53-7	0.000	0.000	0%	0%	0.000	0.000	0%	0%
159	Unknown #20		0.000	0.000	0%	0%	0.000	0.000	0%	0%
160	Unknown #21		0.000	0.000	0%	0%	0.000	0.000	0%	0%
161	Methylindan	27133-93-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
162	1,3-Diisopropylbenzene	00099-62-7	0.000	0.000	0%	0%	0.000	0.000	0%	0%
163.1	1,2,3,4-TetMeBenzene	00488-23-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
163.2	Amylbenz	00538-68-1	0.000	0.000	0%	0%	0.000	0.000	0%	0%
164	Unknown #22		0.000	0.000	0%	0%	0.000	0.000	0%	0%
165	Unknown #23		0.000	0.000	0%	0%	0.000	0.000	0%	0%
166	1,4-Diisopropylbenzene	00100-18-5	0.000	0.000	0%	0%	0.000	0.000	0%	0%
167	Unknown #24		0.000	0.000	0%	0%	0.000	0.000	0%	0%
168	Naphthalene	00091-20-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
169	1-Dodecene	00112-41-4	0.000	0.000	0%	0%	0.000	0.000	0%	0%
170	Unknown #25		0.000	0.000	0%	0%	0.000	0.000	0%	0%
171	Unknown #26		0.000	0.000	0%	0%	0.000	0.000	0%	0%
172	n-Dodecane	00112-40-3	0.000	0.000	0%	0%	0.000	0.000	0%	0%
	Ethanol	00064-17-5	0.000	0.000	0%	0%	0.000	0.000	0%	0%
	Total		241.803	7.624	100%	100%	470.738	14.834	100%	100%

482.047 SHED FID (mg)
97.654 % GC of SHED

Specific Reactivity Calculations - The Carter Maximum Incremental Reactivity (MIR) scale for the various VOC molecules has been adopted by the CARB. It estimates that for each gram of the various VOC molecules, X grams of ozone would be produced under ideal conditions for ozone formation. The reference (approved by the CARB Staff for this purpose) to the values and the documentation is "THE SAPRC-99 CHEMICAL MECHANISM AND UPDATED VOC REACTIVITY SCALES" which can be found at;

http://helium.ucr.edu/~carter/reactdat.htm

The link to the actual data is found down two thirds of the page, under the heading VOC Reactivity Data (Excel format) as of February 5, 2003 (r02tab.xls). Appendix F (pgs 67-77) is a tabulation of MIR values taken from this Excel™ file. It contains CAS number, MIR value and species name for 543 different species.

We calculated the average specific reactivity of the permeate for each of the tests, on each of the rigs, and on each of the three fuels. Speciated data were collected and potential ozone reactivity was calculated for 92 tests, and are contained in the companion CD-ROM for the CRC E65 project as "Individual Reactivity File Calculations – 3 Fuels.xls"

VOC reactivity varies with atmospheric conditions, in particular the VOC/NOx ratio. The MIR scale is based on low VOC/NOx ratios. The reactivity measure reported in this study, average VOC specific reactivity, has units of potential grams of ozone per gram of VOC and is a function of the composition of the VOC permeate. Specific reactivity provides an estimate of the ozone-forming potential per unit mass of the VOC permeate under conditions favorable for ozone formation, but it is not meant to predict actual levels of ozone and should be interpreted on a relative basis. Further, there are uncertainties in these reactivity estimates, e.g., the MIR scale represents a limited range of atmospheric conditions, does not include carryover of emissions from one day to the next, and does not include three-dimensional spatial variation in emissions.

An abbreviated example of the specific reactivity calculations for Rig 1 – Day 1 on Fuel A is shown in Table 10. The left-most column is the elution number, followed by the Species Name, then the CAS Number[8]. The next column is the mass emissions for that compound. The listing has been reordered with the largest mass at the top of the list, then in decreasing order down to the lowest detected levels.

The fifth column is the MIR factor for that molecule. The mass emissions times the MIR gives the theoretical potential ozone that would be formed by that mass under ideal conditions, reported in the 6th or last column. We performed this calculation on all the identified molecules that had MIR factors. Not all the molecules measured had MIR factors. They were assumed to have the same reactivity as the average of the identified compounds with MIR factors. The mass of the compounds for which no MIR factors existed was determined to be insignificant.

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[8] The CAS number is the Chemical Abstract Service registry number assigned to each specific molecule. CAS registry numbers are copyrighted by the American Chemical Society. Redistribution rights for CAS registry numbers are reserved by the American Chemical Society. "CAS registry" is a registered trademark of the American Chemical Society. The CAS REGISTRY mostly covers substances identified from the scientific literature from 1957 to the present with some classes (fluorine- and silicon-containing compounds) going back to the early 1900s. Each substance in REGISTRY is identified by a unique numeric identifier called a CAS Registry Number.

The specific reactivity for a speciated SHED diurnal sample was calculated by summing the mass of the individual species, and the predicted potential ozone using the MIR factor. The specific reactivity is the mass of ozone predicted divided by the mass of the hydrocarbons measured, in our example, 713.9 mg/233.9 mg, or 3.05 g potential O_3/g VOC emissions.

Table 10

Reactivity Calculation Example

	Species Name	CAS #	VOC (mg)	MIR	O_3 (mg)
81	Toluene	00108-88-3	47.503	3.97	188.59
33	MTBE	01634-04-4	33.333	0.78	26.00
18	2-Methylbutane (Isopentane)	00078-78-4	32.940	1.67	55.01
111	m-Xylene	00108-38-3	11.739	10.61	124.55
21	n-Pentane	00109-66-0	10.984	1.53	16.81
36	2-MePentane	00107-83-5	9.176	1.78	16.33
12	n-Butane	00106-97-8	6.863	1.32	9.06
53	Benzene	00071-43-2	6.424	0.81	5.20
40	n-Hexane	00110-54-3	5.789	1.43	8.28
49	Methylcyclopentane	00096-37-7	5.738	2.40	13.77
38	3-Methylpentane	00096-14-0	5.285	2.06	10.89
34	2,3-Dimethylbutane	00079-29-8	4.089	1.13	4.62
63	2,2,4-TriMePentane (IsoOctane)	00540-84-1	3.976	1.43	5.69
111	p-Xylene	00106-42-3	3.600	4.24	15.26
109	Ethylbenzene	00100-41-4	3.575	2.79	9.97
		⇩			
19	1-Pentene	00109-67-1	0.217	7.73	1.68
76	2,5-DiMeHexane	00592-13-2	0.208	1.66	0.35
75	2,4,4-Trimethyl-2-Pentene	00107-40-4	0.207	8.52	1.77
76	EtCyPentane	01640-89-7	0.200	2.25	0.45
101	2,4-Dimethylheptane	02213-23-2	0.192	1.46	0.28
16	c-2-Butene	00590-18-1	0.180	13.22	2.38
39	1-Hexene	00592-41-6	0.147	6.12	0.90
10	1-Butene	00106-98-9	0.130	10.22	1.33
115	Styrene	00100-42-5	0.061	1.94	0.12
		VOC - mg	233.9		713.9 O_3 - mg

Specific Reactivity	3.05

The average specific reactivity (grams of potential ozone/gram of VOC) of the permeate by test fuel type was calculated by averaging the daily values for each of the available tests on each fuel. Table 11 shows the values used for Fuel A.

The first column in Table 11 is the fuel identifier, second is the Test ID (Rig number and the day of the test). The 3rd column, SHED VOC, is the value reported by the SHED test system for the mass (mg) in the SHED (including the EtOH if present). The 4th column is the total mass (mg) reported from the speciation results. The first row of data in the table shows 253 mg reported by the SHED, and 242 mg reported from the speciation – obviously good agreement for two separate analytical techniques. Other comparisons are not as good – "Rig 5 Day 1" differs by more than 500 mg (5%), but is still deemed within laboratory capability.

The 5th column is the mass of the speciated sample that had an assigned MIR factor. The chromatograph identifies VOC species for which there is no MIR factor in the documentation. The mass of the compounds for which no MIR factors existed was determined to be insignificant. It is assumed that this mass had the same average reactivity as the mass for which MIR factors exist.

Twenty tests were available for averaging for Fuel A permeate in Table 11 below. The average Fuel A reactivity of the permeate was 3.47.

Table 11
Average Specific Reactivity of Permeate for Fuel A

Fuel	Test ID	SHED VOC mg	Speciated Total Mass mg	Speciated Mass with MIR Factors mg	Reactivity
A	Rig 1 Day 1	253	242	234	3.05
	Rig 1 Day 2	229	229	222	3.12
	Rig 2 Day 1	655	675	649	3.49
	Rig 2 Day 2	620	602	585	3.31
	Rig 3 Day 1	294	299	290	3.15
	Rig 3 Day 2	283	275	269	2.97
	Rig 4 Day 1	647	649	633	3.24
	Rig 4 Day 2	606	640	620	3.30
	Rig 5 Day 1	9688	9158	8568	3.68
	Rig 5 Day 2	8720	8432	8294	3.77
	Rig 6 Day 1	5358	5081	4872	3.63
	Rig 6 Day 2	3750	3276	3138	3.65
	Rig 7 Day 1	1310	1311	1267	3.66
	Rig 7 Day 2	1086	1100	1072	3.60
	Rig 8 Day 1	950	1242	1221	3.50
	Rig 8 Day 2	968	677	644	3.96
	Rig 9 Day 1	1964	1923	1846	3.68
	Rig 9 Day 2	1964	2016	1932	3.60
	Rig 10 Day 1	1956	1264	1214	3.51
	Rig 10 Day 2	1880	1891	1817	3.44
	Average Fuel A Permeate Specific Reactivity				**3.47**

The values used to calculate the average specific reactivity of the permeate for Fuels B and C are presented in Tables 12 and 13.

Table 12
Average Specific Reactivity of Permeate for Fuel B

Fuel	Test ID	SHED VOC mg	Speciated Total Mass mg	Speciated Mass with MIR Factors mg	Reactivity
	Rig 1 Day 1	1113	1112	1089	2.80
	Rig 1 Day 2	952	878	871	2.78
	Rig 2 Day 1	1527	1503	1463	3.28
	Rig 2 Day 2	1337	1308	1282	3.25
	Rig 3 Day 1	1508	1477	1443	3.12
	Rig 3 Day 2	1228	1185	1160	3.45
	Rig 4 Day 1	2306	2024	1977	2.73
	Rig 4 Day 2	2192	2230	2206	2.79
	Rig 5 Day 1	12517	12671	12156	3.84
	Rig 5 Day 2	10778	11217	10894	3.67
	Rig 6 Day 1	5080	5114	4955	3.75
	Rig 6 Day 2	4706	4955	4803	3.71
	Rig 7 Day 1	2418	2377	2313	3.67
	Rig 7 Day 2	2089	2055	1997	3.42
	Rig 8 Day 1	2939	2781	2739	2.89
	Rig 8 Day 2	2312	2178	2130	2.86
	Rig 9 Day 1	4796	4713	4482	3.33
	Rig 9 Day 2	4553	4451	4410	3.59
	Rig 10 Day 1	3846	3825	3704	3.37
	Rig 10 Day 2	3616	3462	3395	3.47
		Average Fuel B Permeate Specific Reactivity			**3.27**

Table 13

Average Specific Reactivity of Permeate for Fuel C

Fuel	Test ID	SHED VOC mg	Speciated Total Mass mg	Speciated Mass with MIR Factors mg	Reactivity
C	Rig 1 Day 1	253	242	235	3.84
	Rig 1 Day 2	194	144	139	3.26
	Rig 2 Day 1	595	570	555	3.64
	Rig 2 Day 2	571	555	538	3.58
	Rig 3 Day 1	341	359	344	3.46
	Rig 3 Day 2	319	306	304	3.38
	Rig 4 Day 1	1225	1140	1109	3.40
	Rig 4 Day 2	1038	886	858	3.40
	Rig 5 Day 1	12418	12211	11771	3.84
	Rig 5 Day 2	10597	10677	10366	3.84
	Rig 6 Day 1	4269	3878	3737	3.90
	Rig 6 Day 2	3161	3239	3116	3.93
	Rig 7 Day 1	2157	2119	2073	3.38
	Rig 7 Day 2	1668	1638	1623	3.58
	Rig 8 Day 1	902	864	844	4.15
	Rig 8 Day 2	748	785	760	4.10
	Rig 9 Day 1	1839	1795	1743	3.93
	Rig 9 Day 2	1709	1652	1604	3.91
	Rig 10 Day 1	2382	2309	2236	3.63
	Rig 10 Day 2	2222	2084	2020	3.57
		Average Fuel C Permeate Specific Reactivity			**3.66**

Analysis of the above data for all three fuels indicates that there is not a significant difference between the Day 1 and Day 2 results. Given that the Day 2 results are repeats of the Day 1 measurements (as opposed to replicates), the Day 1 and Day 2 results were averaged for further analysis (note that this does not affect the averages by fuel). The data were then fit to the model Reactivity = Fuel + Rig + constant. The average reactivities and the half difference limit based on the Tukey[9] multiple comparisons test with 95% confidence for the three test fuels are shown in Table 14:

Table 14
Permeate Specific Reactivity

	Average Reactivity	95% C.L.
Fuel A	3.47	± 0.107
Fuel B	3.27	± 0.102
Fuel C	3.66	± 0.0753

A plot of the average permeate specific reactivity values and a representation of the Tukey test interval, using an expanded vertical scale, is shown in Figure 16.

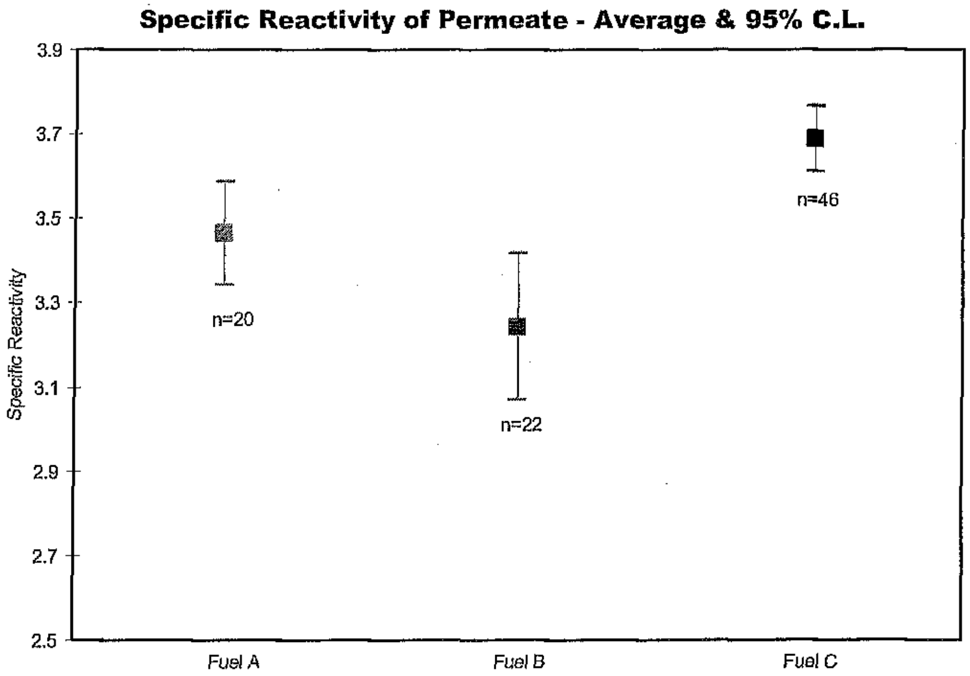

Figure 16

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[9] J.W. Tukey, "Comparing Individual Means in the Analysis of Variance," *Biometrics*, **5**, 99, 1949
The Tukey test is used here to account for the fact that we have more than two test fuels. For two fuels, the Tukey test is just the ordinary Student's t-test. The half least significant difference values are used to *construct the confidence intervals, which enable us to determine whether the differences we measure* between the three test fuels are statistically significant.

The Increase in Non-Ethanol Hydrocarbons with Fuel B – When the first results were accumulated on Fuel B (ethanol), it was observed that not only were the total permeation results higher than Fuel A (MTBE), but the non-ethanol hydrocarbons were also increased. This trend continued throughout the steady-state tests, with only one exception, and is shown in Figure 17. The exception was the Fuel C result on the 1995 MY (Rig 5). The middle bar of each group is the result from Fuel B. The bar is segmented into two components, the non-ethanol contribution in the lower red bar, and the ethanol component stacked on top in a pink color. The total height of the bar is the total permeation emissions as previously reported.

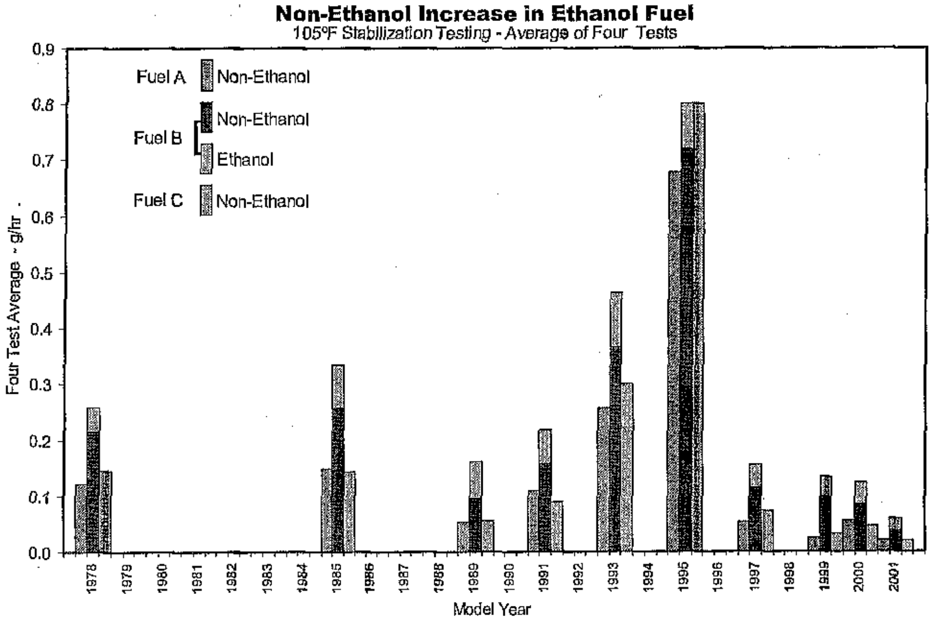

Figure 17

A similar increase was also observed in the results from the diurnal testing. Figure 18 is a similar plot, but showing diurnal test results instead of the steady-state measurements. Three exceptions to the general observation were noted:

1. The 1991 Honda Accord (Rig 7) – The Fuel C diurnal results were higher than the Fuel B non-ethanol hydrocarbons.
2. The 1993 Chevrolet Caprice (Rig 6) – The Fuel A diurnal results were higher than the Fuel B non-ethanol hydrocarbons.
3. The 1995 Ford Ranger (Rig 5) – The Fuel C diurnal results were higher than the Fuel B non-ethanol hydrocarbons, or the total of the non-ethanol and ethanol emissions.

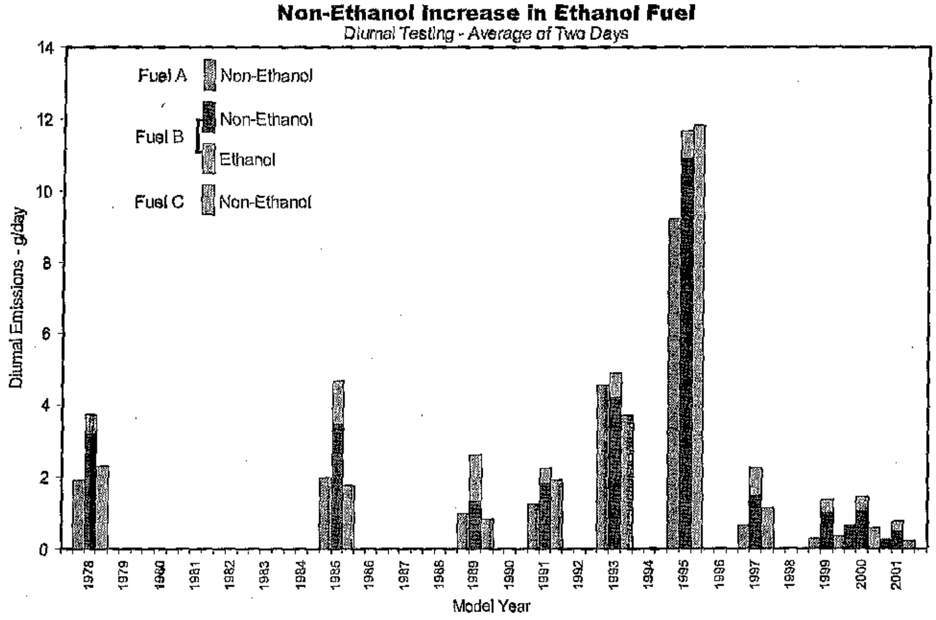

Figure 18

The general understanding is that permeation emissions increase when ethanol is added to gasoline. However there was little anticipation that the non-ethanol fraction would increase. At this time, there is no explanation for the cause of this observation. Two collections of references on the subject of gasoline permeation are included in the Companion CD-ROM: 1- Literature Search Summary – Task 1 –Final.pdf" by Harold Haskew, and 2- "RFA's Literature Search – permeation study.pdf" by Robert Reynolds.

Steady-State Test Results - 105°F and 85°F - The original test plan requirement was to measure the steady-state permeation rate at 85°F, after the rig was deemed to be stabilized at 105°F. The interest in the lower temperature rate was driven by a position taken in a SAE paper, SAE 2001-01-0730, "Estimating Real Time Diurnal Permeation from Constant Temperature Measurements" by Marek Lockhart, et al. The authors suggested that real-time diurnal permeation test results can be estimated from constant temperature measurements. Our measurements add additional basis and support to the above position.

The permeation rates (in milligrams per hour) measured during the program are presented in Table 15.

Table 15
Permeation Rates

		85° F Rate - mg/hr			105° F Rate - mg/hr		
Rig	Description	Fuel A	Fuel B	Fuel C	Fuel A	Fuel B	Fuel C
1	2001 Toyota Tacoma	9	32	10	20	58	19
2	2000 Honda Odyssey	21	53	19	55	123	44
3	1999 Toyota Corolla	10	57	11	24	133	31
4	1997 Chrysler Town & Country	23	66	40	52	155	72
5	1995 Ford Ranger	309	342	348	677	800	801
6	1993 Chevrolet Caprice Classic	95	137	94	255	463	298
7	1991 Honda Accord LX	40	100	39	110	217	88
8	1989 Ford Taurus GL	24	73	28	52	160	55
9	1985 Nissan Sentra	53	177	73	148	333	143
10	1978 Olds Cutlass Supreme	57	139	73	122	257	144
	Average	64	118	73	152	270	170

85° F Rate - If multiple tests were run, the average is shown.
105° F Rate - Rate shown is the average of the last four tests run.

The ratios of the 85°F test results to the 105°F results are shown in Table 16.

Table 16
85°F to 105°F Ratio

		85°/105° Ratio		
Rig	Description	Fuel A	Fuel B	Fuel C
1	2001 Toyota Tacoma	0.46	0.54	0.50
2	2000 Honda Odyssey	0.39	0.43	0.43
3	1999 Toyota Corolla	0.43	0.43	0.37
4	1997 Chrysler Town & Country	0.45	0.43	0.55
5	1995 Ford Ranger	0.46	0.43	0.43
6	1993 Chevrolet Caprice Classic	0.37	0.30	0.32
7	1991 Honda Accord LX	0.36	0.46	0.44
8	1989 Ford Taurus GL	0.45	0.46	0.51
9	1985 Nissan Sentra	0.36	0.53	0.51
10	1978 Olds Cutlass Supreme	0.47	0.54	0.51
	Average	0.42	0.46	0.46

The relationship between the 85°F and the 105°F permeation measurements on Fuel A (as an example) is shown In Figure 19. The horizontal scale is the hourly permeation rate averaged for the last 4 weekly tests at 105°F. The vertical scale is the 85°F rate.

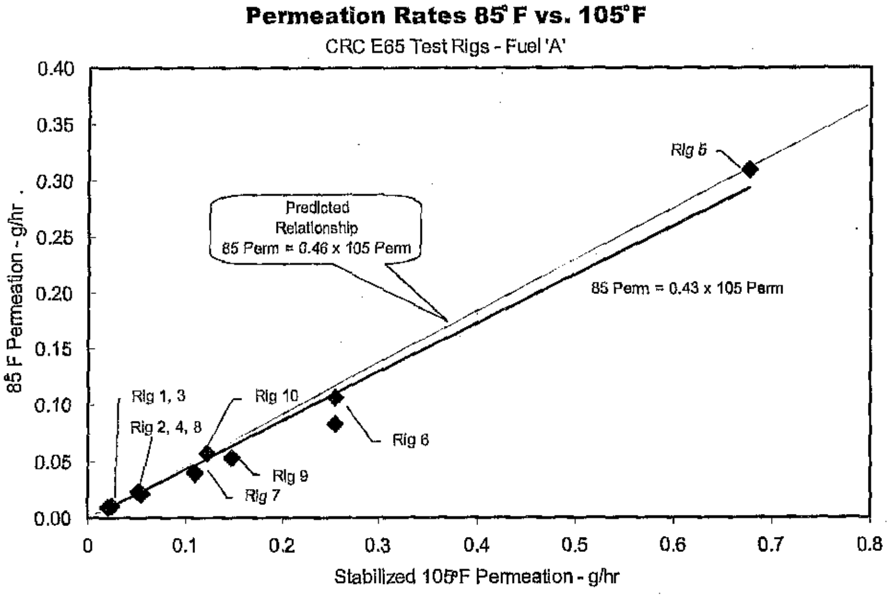

Figure 19

The balloon points to the upper of the two trend lines, which follows the relationship that permeation doubles for each 10°C increase; the rate of 85°F being 46% of the rate of 105°F. The lower line is the slope of the regression line fitted to the data. The data seem to follow the relationship well.

Since Rig 5 had emissions that were much higher than the rest of the fleet, we investigated whether it had a major influence on the relationship by recalculating the regression with the Rig 5 data omitted. Figure 20 shows the data and regression lines with and without Rig 5. The slope of the lines are similar for all three fuels with and without the Rig 5 data included.

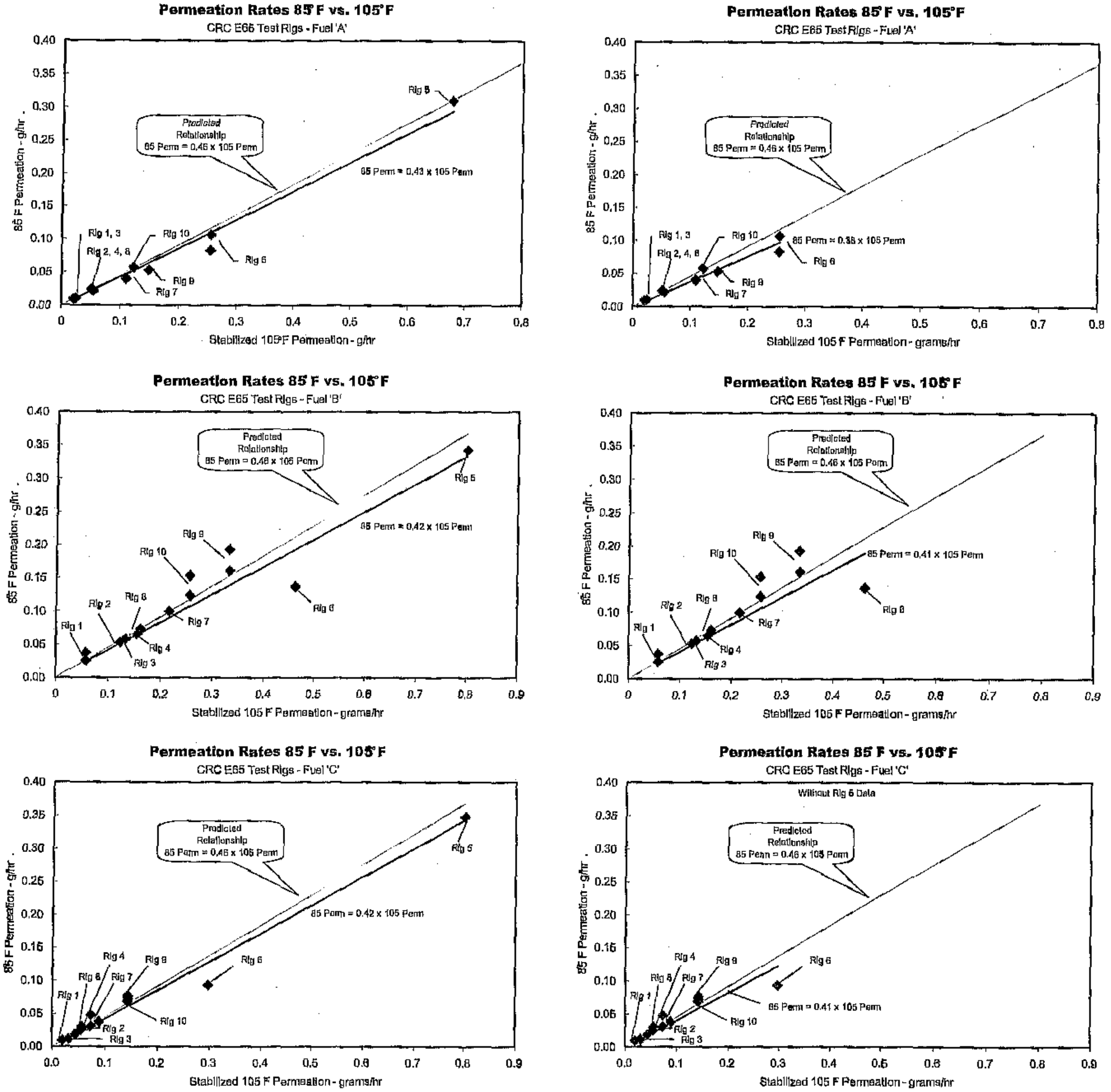

Figure 20

We also determined that the ratio between diurnal emissions and steady-state emissions was fairly consistent. This relationship was also mentioned in SAE paper, SAE 2001-01-0730, "Estimating Real Time Diurnal Permeation from Constant Temperature Measurements" by Marek Lockhart, et al. Figure 21 plots the diurnal and 105°F steady-state emissions. The ratio for the three fuels was 14.1.

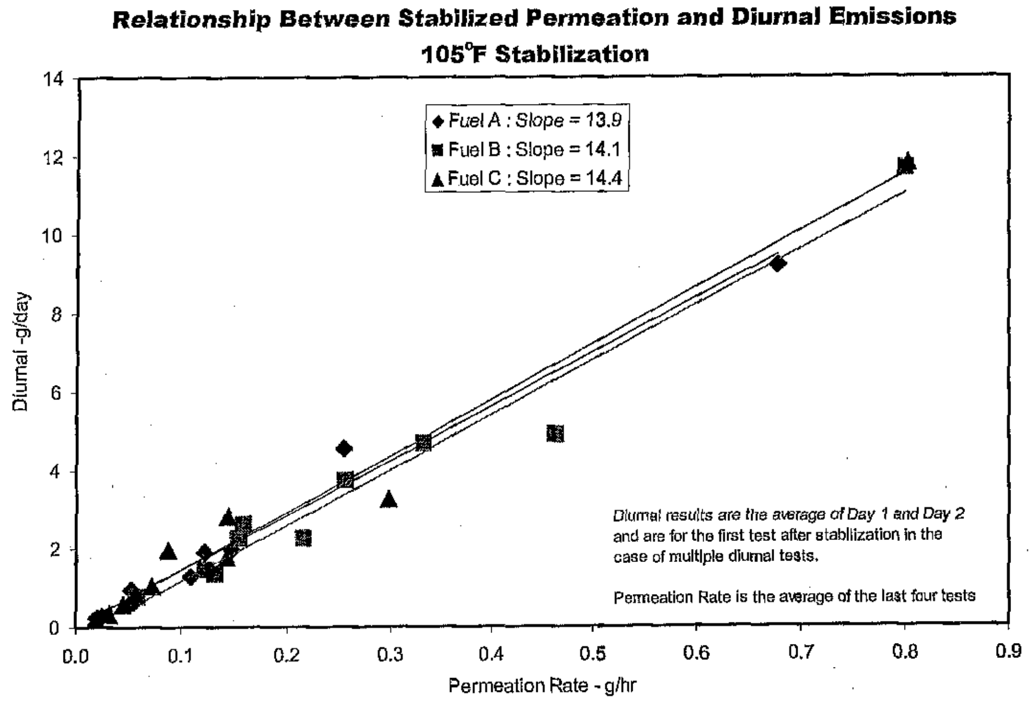

Figure 21

Estimate of Experimental Variation – After completion of the base program, replicate testing was performed on Fuel C to estimate the "repeatability" of the diurnal test results. This resulted in 9 pairs of "repeats" for Day 1 and Day 2. The repeatability data are presented in Table 17.

Table 17
Replicate Diurnal Test Results – Fuel C

Rig 01C	**Day 1**	**Day 2**
Original Test Measurement (g/day)	0.278	0.174
Replicate	0.226	0.214
Rig 02C	**Day 1**	**Day 2**
Original Test Measurement (g/day)	0.593	0.583
Replicate	0.598	0.559
Rig 03C	**Day 1**	**Day 2**
Original Test Measurement (g/day)	0.340	0.310
Replicate	0.342	0.328
Rig 04C	**Day 1**	**Day 2**
Original Test Measurement (g/day)	1.109	1.004
Replicate	1.341	1.071
Rig 05C	**Day 1**	**Day 2**
Original Test Measurement (g/day)	13.571	11.268
Replicate	11.952	10.207
Rig 06C	**Day 1**	**Day 2**
Original Test Measurement (g/day)	3.568	2.979
Replicate	4.697	2.947
Rig 07C	**Day 1**	**Day 2**
Original Test Measurement (g/day)	2.230	1.712
Replicate	2.084	1.623
Rig 09C	**Day 1**	**Day 2**
Original Test Measurement (g/day)	1.874	1.697
Replicate	1.803	1.721
Rig 10C	**Day 1**	**Day 2**
Original Test Measurement (g/day)	2.809	2.832
Replicate	2.288	1.820

Rig 8 was not included in the replicate test program. The ~6 month time interval between when Rig 8 completed the Base Program and initiation of the Replicate Program was thought to be too long for the results to be acceptable.

The replicate data were used to determine the statistical significance of the effect of fuel changes on the diurnal emissions. First, the data by day were averaged, then the diurnal data for all three fuels were fit to a model designed to isolate the replicates in the determination of the experimental error (Diurnal emissions = Fuel + Rig + FuelxRig). The average permeation emissions of each of the three fuels, and the half difference limit based on the Tukey multiple comparisons test with 95% confidence, are shown in Table 18 below for the three test fuels:

Table 18
Diurnal Emissions

	Average Diurnal Emissions (g/day)	95% Limit
Fuel A	2.16	± 0.243
Fuel B	3.56	± 0.243
Fuel C	2.45	± 0.185

A plot of the average diurnal emissions values and a representation of the Tukey test interval, using an expanded vertical scale, is offered in Figure 22 below:

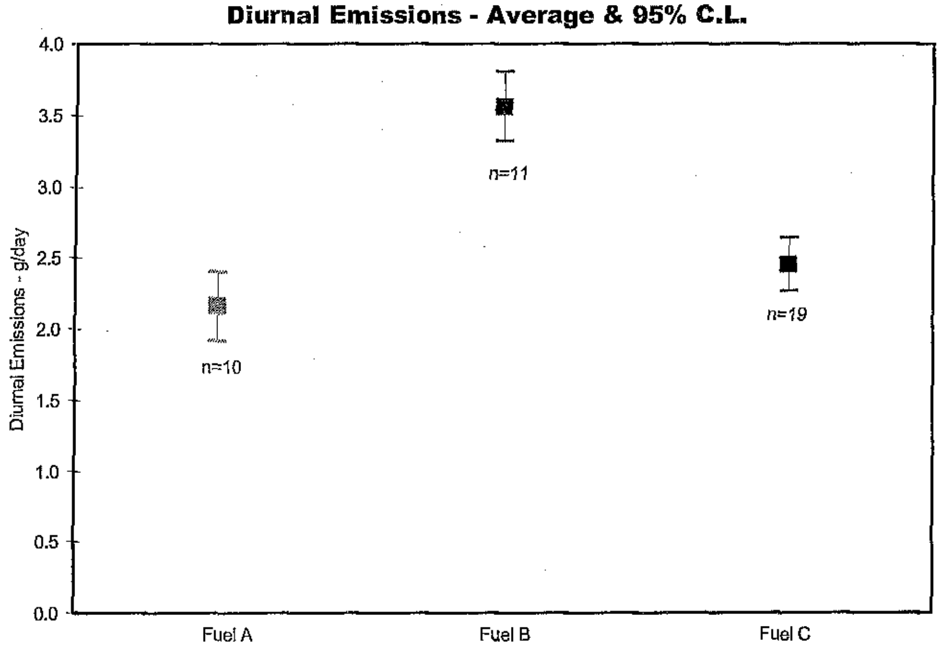

Figure 22

The analysis of the diurnal test results indicates that the differences between the ethanol fuel (Fuel B) and the other two fuels are statistically significant at the 95% confidence level. The difference between the emissions of the MTBE and non-oxygenated fuels are not significant at the 95% confidence level.

Effect of Preconditioning Fill Level on Non-Metallic Tank Systems (100% vs. 20%) - Four of the ten rigs featured non-metallic fuel tanks, and we wanted to determine the effect of the fill level on the permeation results. The basic procedure followed during the program was to soak the tanks with a 100% fill as we thought that this could give the fastest stabilization, and minimize the effects of the fuel "weathering" over time. We conducted additional stabilization on the four rigs with the non-metallic tanks at the end of the program, filling to 20% of capacity with Fuel C, re-stabilizing at 105°F, and then testing at 85°F, and conducting a two-day diurnal (diurnals are always conducted with a fresh fill of 40% of the test fuel). The results are presented in Table 19:

Table 19
Fill Level Effect - Steady-state Test Results

	100% fill	20% fill	% Change
105°F test results	-------- g/hour --------		
Rig 2	0.044	0.033	-25
Rig 4	0.072	0.056	-22
Rig 5	0.820	0.750	-9
Rig 6	0.298	0.277	-7
Average	0.308	0.279	
85°F test results			
Rig 2	0.019	0.013	-32
Rig 4	0.041	0.021	-49
Rig 5	0.349	0.350	0
Rig 6	0.094	0.095	+1
Average	0.126	0.120	

Diurnal Test Results (40% fill)

	100% fill	20% fill	% Change
	Preconditioning		
Day 1	--------- g/day ---------		
Rig 2	0.596	0.435	-27
Rig 4	1.225	0.791	-35
Rig 5	11.952	12.857	+8
Rig 6	4.132	4.541	+10
Average	4.476	4.656	
Day 2			
Rig 2	0.571	0.422	-26
Rig 4	1.038	0.673	-35
Rig 5	10.207	10.982	+8
Rig 6	2.963	3.558	+20
Average	3.695	3.909	

The fill level test results are mixed. The newer fuel tank systems (rigs 2 and 4) showed lower permeation at lower fill levels on both the steady-state measurements, and on the 48 hour diurnal tests, despite the fact that the fill level during the actual diurnal test was unchanged at 40%. Rigs 5 and 6 showed slightly lower steady-state permeation rates (-7 and -9% of level) during the 105°F tests, but no difference at 85°F. The permeation rates increased during the diurnal evaluation.

Appendix A

Evaporative Emissions

The purpose of this project was to quantify the permeation emissions from a variety of vehicle fuel systems with three different fuel compositions used or contemplated for use in California. One of the challenges was to isolate the permeation component from the other sources of fuel, and non-fuel, emissions. This section documents the development of the evaporative emission test and the hardware used to control the emissions, and illustrates the solutions we used to focus only on the permeation emissions. We first discuss total evaporative emissions, the issue of "breathing losses", permeation, then the steps we took to measure only permeation emissions.

Permeation is one component in the total evaporative emissions from a vehicle. The purpose of this section is to define and document permeation's role in evaporative emissions

Evaporative emissions from motor vehicles can be defined as all the hydrocarbon (HC) emissions from a vehicle that do not come from the engine's exhaust[10]. These non-tailpipe hydrocarbons come from a variety of sources, including non-fuel "background" sources such as tires, paint, vinyl components, and adhesives[11]. The major source of evaporative emissions has been from the vehicle's fuel storage, delivery and handling systems.

The fuel tank, by design, is vented to the atmosphere through an activated carbon trap, and the normal daily tank emissions are highly controlled. Gasoline also escapes the vehicle's fuel system by permeation through the plastic and rubber components; e.g., hoses, seals, and in some cases, such as with a non-metallic tank, the fuel tank itself. Advances in materials and design have reduced the permeation emissions component to very low levels.

An unintended source of HC emissions may occur from leaks in the system. Leaks may occur in the vapor and/or the liquid system as a result of deterioration and/or faulty service techniques.

Examples of deterioration are corrosion of metallic components (e.g., fuel lines, tanks), cracking of rubber hoses from heat and ozone exposure, hardening of seals, and mechanical failures. Deterioration of the elastomers has been greatly reduced for vehicles built in the middle 90s and later which are certified to the 10 year/100,000 mile requirements. The most restrictive emission control requirement is the California "Zero-Fuel-Evaporative Emissions", which states that fuel emissions must be 0.0 g/day (less than 54 milligrams/day) for 15 years, or 150,000 miles.

Poor service techniques include the failure to properly reinstall and tighten connections, the use of inadequate repair materials, and the defeat (intended or unintended) of control devices such as valves and switches.

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[10] William R. Pierson, et al., "Assessment of Nontailpipe Hydrocarbon Emissions from Motor Vehicles", Journal of the Air & Waste Management Association, Volume 49 May 1999, ISSN 1047-3289

[11] Harold M. Haskew, "Real-Time Non-Fuel Background Emissions", SAE 912373, International Fuels and Lubricants Meeting, Toronto, Canada, Oct 7-10, 1991.

Appendix B

A Vehicle's Fuel System

Evaporative emissions can escape from a wide variety of places on the vehicle. The purpose of this section is to define some terms and illustrate where leaks might occur.

Figure 23 is a simplified schematic of a typical vehicle fuel system. The fuel tank is usually located at the rear of the vehicle. A vapor volume space is provided above the liquid, even when the tank is "full", to allow for expansion, and help with the separation of the liquid from the vapor. The fill neck can be a separate component, connected to the tank in one or more places with rubber hose(s) and *clamp(s)*. An external fill vent hose may be fitted from the top of the tank to the filler neck pocket.

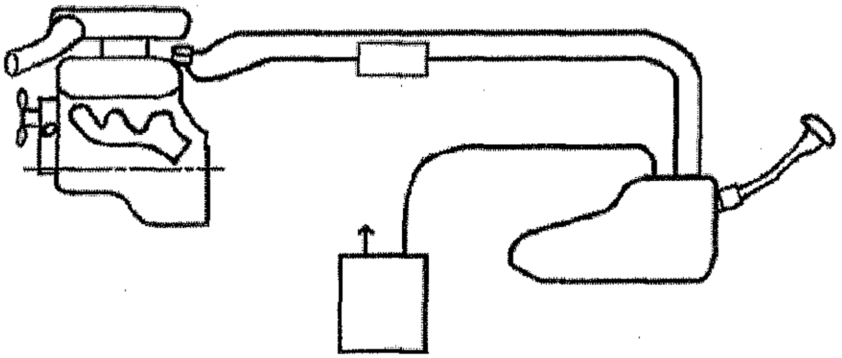

Figure 23. Vehicle Fuel System Schematic

Fuel injection vehicles typically have a fuel supply pump, mounted in the tank, drawing fuel from the bottom of the tank through a primary filter, or "sock". The supply pressure is maintained typically in the 10 psi range for throttle body injection systems, typical of the 1980's. Higher pressures, 40 to 60 psi, are used for port fuel injection systems.

The chassis supply line, typically a 8mm id tube, carries the pressurized fuel to the engine. The chassis supply line has typically been steel, and rigidly mounted to the underbody of the vehicle. Nylon has also been used for a number of years, and offers *superior corrosion resistance*. A serviceable fuel filter is usually fitted in the supply line. The chassis supply line is connected to the tank with a flexible hose for assembly, service, and isolation reasons. A similar flexible connection is made to the engine at the front of the vehicle. Many engine fuel systems use an engine mounted pressure regulator and *return excess fuel back to the tank through* a duplicate chassis return line. While the return line is not at the supply pressure, it is still pressurized, and an important component.

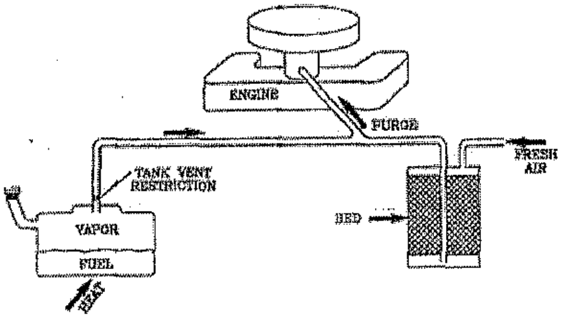

Figure 24. Evaporative Emission Control

Vapors from the tank are routed through a tank vent tube to a carbon canister for storage. The canister may be located in the engine compartment, which requires a long vapor tube, or close to the tank, which is required for the late 90's models with on-board control of refueling vapors. Vehicle motion can produce "slosh" in the tank, and liquid can be trapped in the vent unless provisions have been made to separate it. Some applications use special liquid/vapor separators to ensure that only vapor is routed to the carbon canister. The canister is reactivated, or purged during engine operation by using engine vacuum to draw air through the carbon bed. The canister then has at least three connections, 1) the tank vapor vent, 2) the purge line, and 3) an air supply port.

The purge line to the engine may have a solenoid and/or a coolant temperature operated switch affixed to control the purge. This is sometimes mounted directly on the canister – other times on the engine. The vapor part of the system is therefore: the top of the tank, the fill pipe, the fill cap, the tank vent hose(s), the purge line, solenoids and switches, and the fresh air vent for the canister.

Appendix C

Isolating the Breathing Loss Emissions

The intent was to measure the permeation performance of the vehicle fuel systems from vehicles in good repair. A brief review of fuel vapor emissions, including the "breathing losses" may be helpful. The tank, hoses, and controls are designed to contain the gasoline. Gasoline can escape the system by several mechanisms:

- Leaks
- Breathing losses (Vapor expelled during system temperature increases)
- Permeation

Leaks are an anomaly, and while they are present in the population of vehicles, are not thought to be sensitive to gasoline composition. By selecting vehicles in good repair, leaks should be eliminated from the measurements, even though this requirement would offer a possible challenge on the older vehicles.

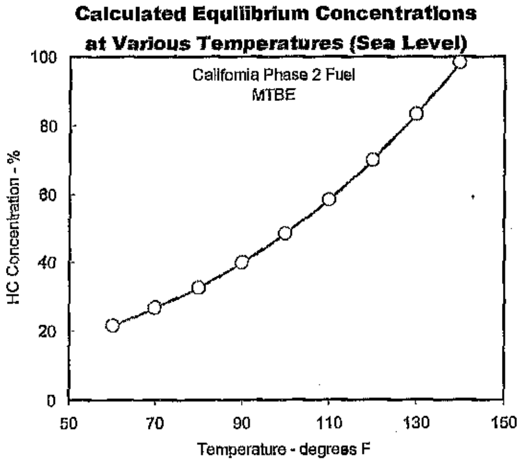

Figure 25

Breathing losses are sometimes called "diurnal" losses and result from the fact that a vented fuel tank has to expel air and vapors during a temperature increase. A parked vehicle experiences temperature changes as the ambient temperature rises and then falls during the daily, or "diurnal" cycle. The plot in Figure 25 presents the equilibrium concentration of HC in the vented vapor space above liquid gasoline (such as would occur in an automotive fuel tank) for a range of temperatures.

For example, at 70°F, the equilibrium concentration of hydrocarbons in the vapor space above the liquid fuel is 27%. If the temperature is increased to 80°F, the vapor pressure increases, and the equilibrium concentration in the vapor space increases to 32%. If the HC concentration above the fuel has to increase, and the vapor space is vented to the atmosphere and no pressure increase can result, some vapor must be expelled. This is what we refer to as the "breathing loss."

As described earlier, automotive evaporative emission control systems capture these expelled vapors in a canister filled with activated carbon (See SAE 902119, "Performance of Activated Carbon in Evaporative Loss Control Systems", by H.R. Johnson and R.S. Williams). The HC molecules are temporarily stored on the carbon bed, and returned to the engine for combustion by drawing air through the bed while the engine is running.

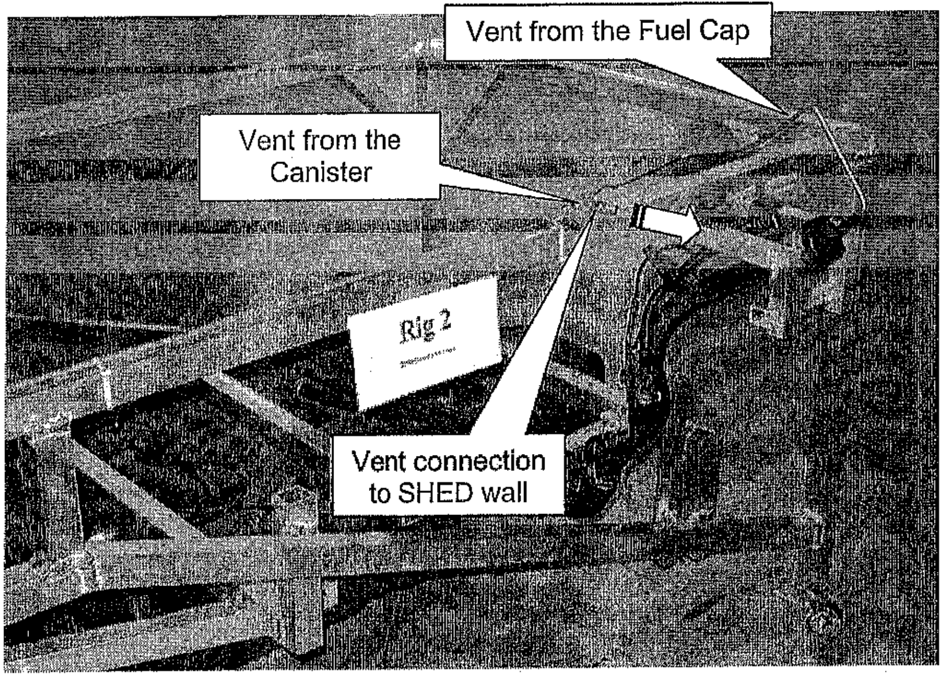

Figure 26. Test Rig 2

For the purposes of this project, we were able to eliminate the contribution of the breathing losses by affixing a tube to the fuel tank system's atmospheric vent and routing the vapors to the outside of the SHED through a bulk-head fitting in the enclosure. We also affixed a vent to the fuel cap, and combined this with the external vent, to prevent any pressurization in case a pressure control valve was fitted to the tank (an example is shown in Figure 26).

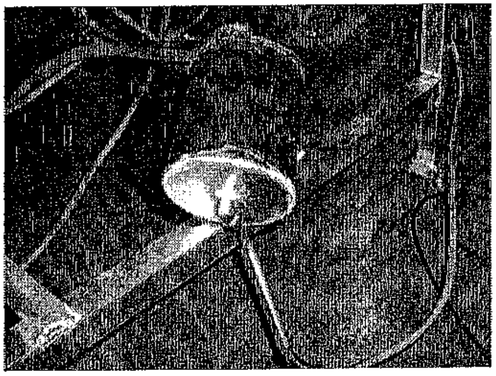

Figure 27. Open Bottom Canister

Figure 27 shows the fabricated cap that was fashioned and fitted to the open bottomed canister of Rig 10 (1978 Cutlass) to collect and route the canister vapors to the fittings that took any vapors outside the SHED.

Appendix D

Evaporative Emission Control Regulations

Evaporative emissions were first controlled nation-wide[12] in model year 1971. Carburetor and fuel tank vapors were routed to a small (about one liter) container of activated carbon for temporary storage and eventual use by the engine. Basic evaporative control hardware concepts (Carbon storage for tank vapors) have not changed much since then, but control effectiveness has increased greatly as materials, understanding and measurement techniques have improved.

The following summary provides an overview of the evolution of evaporative emission control regulations. These apply to Federal light-duty vehicles. California typically adopted regulations prior to the Federal rule. The model year that the regulation first affected is listed at the left margin. Many rules were phased in over three or more years.

1971	Carbon Trap Based Requirements (Diurnal + Hot Soak)[13] Diurnal test of 1 hour – Fuel heated from 60 to 84°F Hot Soak of 1 hour at Lab temperature after urban driving cycle
1978	Enclosure Based (SHED) Requirements – 6.0 grams[14] Diurnal test of 1 hour – Fuel heated from 60 to 84°F Hot Soak of 1 hour at Lab temperature after urban driving cycle
1981	Enclosure Based (SHED) Requirements – 2.0 grams[15] Diurnal test of 1 hour – Fuel heated from 60 to 84°F Hot Soak of 1 hour at Lab temperature after urban driving cycle
1996 to 1998	Enhanced Evaporative Emission Regulations - 2.0 grams (Multi-Day Diurnal & Running Loss)[16] Diurnal test of 24 hours – multiple days – Ambient temp heated from 65 to 105°F for California models with 7.0 psi RVP fuel. Federal test at 72 to 96°F with 9.0 psi RVP fuel. Certification Durability Requirements extended to 10 Years/ 100,000 miles. Hot Soak of 1 hour at elevated temperature following extended high temperature driving Running Losses controlled to 0.05 g/mile

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[12] California typically has required controls one or more years prior to the Federal requirement.

[13] 33 FR 8304, June 4, 1968, "Standards for Exhaust Emissions, Fuel Evaporative Emissions, and Smoke Emissions, Applicable to 1970 [sic.] and Later Vehicles and Engines"

[14] 41 FR 25626, August 23, 1976, "Final Evaporative Emission Regulations for Light Duty Vehicles and Trucks"

[15] 43 FR 37970, August 24, 1978, "Evaporative Emission Regulations for Light-Duty Vehicles and Trucks"

[16] 58 FR 16002, March 24, 1993, "Evaporative Emission Regulations for Gasoline and Methanol-Fueled Light-Duty Vehicles, Light-Duty Trucks, and Heavy-Duty Vehicles"

1998 to 2000 On-Board Refueling Emission Controls[17] (Light duty Trucks from 2000 to 2004)
Refueling control added to enhanced evap requirements

California required on-board diagnostic systems starting with model year 1988[18]. California later expanded the diagnostic requirements[19] to include (among many other things) leak checks on the evaporative control system, first affecting model year 1994. EPA adopted the California OBD II requirements[20] and required them on federal vehicles starting in model year 1998.

Appendix E

Sealed Housing For Evaporative Determination (SHED)

The enclosure technique for measuring evaporative emissions was first adopted for 1978 model year vehicle certification. The test subject is placed in a leak-proof box (Figure 6), and observed for a period of time. If fuel vapors are being emitted, the hydrocarbon concentration in the enclosure will increase. The mass of fuel vapors in the enclosure is calculated at the start of the observation period, and then again at some period later. The difference in the two estimates divided by the elapsed time is the time rate of mass emissions.

"Hot soak" emissions are measured over a 1 hour period (e.g., 40 CFR § 86.138-90). Mass is calculated from the net volume in the enclosure, the concentration of the fuel vapors, and the assumed average density of the mixture of vapors in the sample. The density is corrected for the local temperature and station pressure. The difference in fuel vapor mass over a period of time is the mass rate of emissions. The following quote is taken from the federal emissions test procedure at 40 CFR § 86.138-78 (The later procedures, -90 and -96 include methanol corrections, and are difficult to follow):

The basic form of the calculation is: Mass = Volume * Concentration * Density

The Federal Register procedure is copied below.

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[17] 59 FR 16262, April 6, 1994, "Refueling Emission Regulations for Light-Duty Vehicles and Light-Duty Trucks"

[18] Title 13 – California Code of Regulations section 1968

[19] Title 13 – California Code of Regulations section 1968.1

[20] Federal Register, 58 FR 9468, Feb. 19, 1993

§ 86.143–78 Calculations; evaporative emissions.

The calculation of the net hydrocarbon mass change in the enclosure is used to determine the diurnal and hot soak mass emissions. The mass is calculated from initial and final hydrocarbon concentrations in ppm carbon, initial and final enclosure ambient temperatures, initial and final barometric pressures, and net enclosure volume using the following equation:

$$M_{HC}=kV_n\times10^{-4}\left[\frac{C_{HCf}P_{Bf}}{T_f}-\frac{C_{HCi}P_{Bi}}{T_i}\right]$$

Where:

M_{HC} = hydrocarbon mass, g.

C_{HC} = hydrocarbon concentration as ppm carbon.

V_n = net enclosure volume, ft^3 (m^3) as determined by subtracting 50 ft^3 (1.42 m^3) (volume of vehicle with trunk and windows open) from the enclosure volume. A manufacturer may use the measured volume of the vehicle (instead of the nominal 50 ft^3) with advance approval by the Administrator: *Provided*, The measured volume is determined and used for all vehicles tested by that manufacturer.

P_B = barometric pressure, in. Hg (kPa).

T = enclosure ambient temperature, R (K).

k = .208 (12+H/C)

for SI units, k = 1.2 (12+H/C).

Where:

H/C = Hydrogen-carbon ratio.

H/C = 2.33 for diurnal emissions.

H/C = 2.2 for hot soak emissions.

i = indicates initial reading.

f = indicates final reading.

The final reported results shall be computed by summing the individual evaporative emission results determined for the diurnal breathing-loss test, running-loss test, and the hot-soak test.

The volume of the enclosure is established with some degree of accuracy. The volume of the vehicle with the windows and trunk lid open is assumed to be 50 ft^3, unless a more appropriate value is known. We used 5 ft^3 as an appropriate volume for the rigs. The SHEDs used were nominally 2000 ft^3 in volume, so even plus or minus 5 ft^3 for the net volume estimate is a small error.

ATL has 6 SHEDs (5 variable temperature, and 1 constant temperature) at the Mesa, AZ facility, as shown in Figure 28. These are basically aluminum boxes, 10' x 10' in width and height, and 20' long, with the necessary heating/cooling systems, HC sampling systems, and volume compensation devices for the VT-SHED models.

The sampling system draws a continuous sample from the enclosure during the test through a pump and pressure control device. A small portion is routed to the Flame Ionization Detector (FID) (See SAE 700468 and 770141 for FID basics) for establishing the hydrocarbon concentration in the sample. The balance of the sample is returned to the enclosure.

The one hour interval used for the automotive hot soak, and the 24 hour interval used to estimate the daily "diurnal" emissions, are the normally measured parameters. The concept of the enclosure method can be used over shorter intervals, and allow more information to be gained during a test.

Figure 28. ATL SHEDs

Appendix F

Carter Reactivity Scale – Maximum Incremental Reactivity

CAS No.	MIR	Species
50-00-0	8.96	Formaldehyde
56-23-5	0.00	Carbon Tetrachloride
56-81-5	3.26	Glycerol
57-55-6	2.74	Propylene Glycol
60-29-7	4.01	Diethyl Ether
64-17-5	1.69	Ethanol
64-18-6	0.08	Formic Acid
64-19-7	0.50	Acetic Acid
66-25-1	4.93	Hexanal
67-56-1	0.69	Methanol
67-63-0	0.71	Isopropyl Alcohol
67-64-1	0.43	Acetone
67-66-3	0.03	Chloroform
67-68-5	6.83	Dimethyl Sulfoxide
71-23-8	2.73	n-Propyl Alcohol
71-36-3	3.33	n-Butyl Alcohol
71-41-0	3.33	Pentyl Alcohol
71-43-2	0.81	Benzene
71-55-6	0.00	1,1,1-Trichloroethane
74-82-8	0.01	Methane
74-83-9	0.02	Methyl Bromide
74-84-0	0.31	Ethane
74-85-1	9.07	Ethene
74-86-2	1.24	Acetylene
74-87-3	0.03	Methyl Chloride
74-95-3	0.00	Methylene Bromide
74-96-4	0.11	Ethyl Bromide
74-98-6	0.56	Propane
74-99-7	6.44	Methyl Acetylene
75-00-3	0.25	Ethyl Chloride
75-01-4	2.92	Vinyl Chloride
75-04-7	7.79	Ethyl Amine
75-07-0	6.83	Acetaldehyde
75-09-2	0.07	Dichloromethane
75-18-3		Dimethyl Sulfide
75-19-4	0.10	Cyclopropane
75-21-8	0.04	Ethylene Oxide
75-28-5	1.34	Isobutane
75-34-3	0.10	1,1-Dichloroethane
75-35-4		1,1-Dichloroethene
75-50-3	7.06	Trimethyl Amine
75-56-9	0.32	Propylene Oxide
75-65-0	0.45	t-Butyl Alcohol
75-83-2	1.33	2,2-Dimethyl Butane
75-97-8	0.78	Methyl t-Butyl Ketone
77-68-9	0.86	3-Hydroxy-2,2,4-Trimethylpentyl-1-Isobutyrate

77-76-9	0.52	2,2-Dimethoxy Propane
78-59-1	10.58	isophorone {3,5,5-trimethyl-2-cyclohexenone}
78-78-4	1.67	Iso-Pentane
78-79-5	10.68	Isoprene
78-83-1	2.23	Isobutyl Alcohol
78-84-2	5.86	2-Methylpropanal
78-85-3	6.18	Methacrolein
78-87-5		1,2-Dichloropropane
78-92-2	1.59	s-Butyl Alcohol
78-93-3	1.48	Methyl Ethyl Ketone
78-94-4	8.67	Methylvinyl ketone
78-98-8	16.21	Methyl Glyoxal
79-00-5	0.06	1,1,2-Trichloroethane
79-01-6	0.60	Trichloroethylene
79-09-4	0.79	Propionic Acid
79-10-7	11.57	Acrylic Acid
79-14-1	2.67	Glycolic Acid
79-20-9	0.07	Methyl Acetate
79-21-0		Peroxyacetic Acid
79-29-8	1.13	2,3-Dimethyl Butane
79-31-2	1.22	isobutyric acid
79-41-4	18.78	Methacrylic Acid
80-56-8	4.29	a-Pinene
80-62-6	15.84	Methyl Methacrylate
89-78-1	1.70	menthol
90-12-0	4.61	1-Methyl Naphthalene
91-08-7		2,6-Toluene Diisocyanate
91-20-3	3.26	Naphthalene
91-57-6	4.61	2-Methyl Naphthalene
94-65-5	1.71	2-propyl cyclohexanone
94-96-2	2.62	2-Ethyl-1,3-hexanediol
95-13-6	3.21	Indene
95-47-6	7.48	o-Xylene
95-48-7	2.34	o-Cresol
95-63-6	7.18	1,2,4-Trimethyl Benzene
96-14-0	2.06	3-Methylpentane
96-22-0	1.44	3-Pentanone
96-26-4	4.02	dihydroxyacetone
96-33-3	12.10	Methyl Acrylate
96-37-7	2.40	Methylcyclopentane
96-41-3	1.94	Cyclopentanol
96-47-9	4.59	Alpha-Methyltetrahydrofuran
96-48-0	1.15	gamma- butyrolactone
97-64-3	2.72	Ethyl Lactate
97-85-8	0.61	Isobutyl Isobutyrate
97-86-9	8.98	Isobutyl Methacrylate
97-88-1	9.08	Butyl Methacrylate
97-99-4	3.54	tetrahydro-2-furanmethanol
98-08-8	0.26	Benzotrifluoride
98-55-5	5.16	a-terpineol
98-56-6	0.11	p-Trifluoromethyl-Cl-Benzene

98-82-8	2.32	Isopropyl Benzene (cumene)
98-83-9	1.71	a-Methyl Styrene
98-95-3	0.07	Nitrobenzene
100-41-4	2.79	Ethyl Benzene
100-42-5	1.94	Styrene
100-52-7	-0.61	Benzaldehyde
101-68-8	0.79	Methylene Diphenylene Diisocyanate
102-71-6	2.75	Triethanolamine
102-76-1	0.57	glyceryl triacetate
103-09-3	0.77	2-Ethyl-Hexyl Acetate
103-11-7	2.42	2-Ethyl-Hexyl Acrylate
103-65-1	2.20	n-Propyl Benzene
104-51-8	1.97	n-Butyl Benzene
104-76-7	2.18	2-Ethyl-1-Hexanol
105-05-5	3.36	p-Diethyl Benzene
105-37-3	0.79	Ethyl Propionate
105-46-4	1.43	s-Butyl Acetate
105-54-4	1.24	Ethyl Butyrate
105-57-7	3.68	acetal (1,1-diethoxyethane)
105-66-8	1.15	n-Propyl Butyrate
106-21-8	1.42	3,7-dimethyl-1-octanol
106-36-5	0.92	n-Propyl Propionate
106-42-3	4.24	p-Xylene
106-44-5	2.34	p-Cresol
106-46-7	0.20	p-Dichlorobenzene
106-63-8	5.05	isobutyl acrylate
106-65-0	0.23	Dimethyl Succinate
106-79-6	0.48	Dimethyl Sebacate
106-88-7	1.01	1,2-Epoxybutane
106-93-4	0.05	1,2-Dibromoethane
106-94-5	0.35	n-Propyl Bromide
106-97-8	1.32	n-Butane
106-98-9	10.22	1-Butene
106-99-0	13.47	1,3-Butadiene
107-00-6	6.18	Ethyl Acetylene
107-02-8	7.55	Acrolein
107-06-2	0.10	1,2-Dichloroethane
107-13-1		Acrylonitrile
107-21-1	3.36	Ethylene Glycol
107-22-2	14.22	Glyoxal
107-31-3	0.06	Methyl Formate
107-40-4	8.52	2,4,4-trimethyl-2-Pentene
107-41-5	1.03	2-Methyl-2,4-Pentanediol
107-46-0		Hexamethyldisiloxane
107-83-5	1.78	2-Methyl Pentane
107-87-9	3.06	2-Pentanone
107-92-6	1.78	butanoic acid
107-98-2	2.60	1-Methoxy-2-Propanol
108-01-0	4.75	Dimethylaminoethanol
108-05-4	3.26	Vinyl Acetate
108-08-7	1.63	2,4-Dimethyl Pentane

108-10-1	4.28	4-Methyl-2-Pentanone
108-11-2	2.89	4-methyl-2-pentanol (methyl isobutyl carbinol)
108-20-3	3.56	diisopropyl ether
108-21-4	1.12	Isopropyl Acetate
108-32-7	0.25	Propylene Carbonate
108-38-3	10.61	m-Xylene
108-39-4	2.34	m-Cresol
108-65-6	1.69	1-Methoxy-2-Propyl Acetate
108-67-8	11.22	1,3,5-Trimethyl Benzene
108-82-7	2.37	2,6-dimethyl-4-heptanol
108-83-8	2.90	Di-isobutyl ketone (2,6-dimethyl-4-heptanone)
108-84-9	1.46	methyl amyl acetate (4-methyl-2-pentanol acetate)
108-87-2	1.97	Methylcyclohexane
108-88-3	3.97	Toluene
108-90-7	0.36	Monochlorobenzene
108-93-0	2.23	Cyclohexanol
108-94-1	1.59	Cyclohexanone
108-95-2	1.82	Phenol
109-21-7	1.10	n-Butyl Butyrate
109-60-4	0.86	Propyl Acetate
109-65-9	0.60	n-Butyl Bromide
109-66-0	1.53	n-Pentane
109-67-1	7.73	1-Pentene
109-69-3		1-Chlorobutane
109-86-4	2.97	2-Methoxyethanol
109-87-5	1.04	Dimethoxy methane
109-94-4	0.52	Ethyl Formate
109-99-9	4.91	Tetrahydrofuran
110-00-9	16.54	Furan
110-12-3	2.10	5-Methyl-2-Hexanone
110-19-0	0.67	Isobutyl Acetate
110-43-0	2.77	2-Heptanone
110-49-6	1.18	2-Methoxyethyl Acetate
110-54-3	1.43	n-Hexane
110-62-3	5.71	Pentanal (Valeraldehyde)
110-63-4	3.22	1,4-butanediol
110-74-7	0.92	n-Propyl Formate
110-80-5	3.76	2-Ethoxyethanol
110-82-7	1.44	Cyclohexane
110-83-8	5.40	Cyclohexene
110-98-5	2.47	Dipropylene Glycol Isomer (1-[2-hydroxypropyl]-2-propanol)
111-13-7	1.64	2-Octanone
111-15-9	1.88	2-Ethoxyethyl Acetate
111-27-3	2.72	1-Hexanol
111-30-8	4.79	Glutaraldehyde
111-35-3	4.22	3-Ethoxy-1-Propanol
111-42-2	4.05	Diethanol Amine
111-43-3	3.23	Di n-Propyl Ether
111-46-6	3.53	Diethylene Glycol
111-55-7	0.73	Ethylene Glycol Diacetate
111-65-9	1.09	n-Octane

111-66-0	3.42	1-Octene
111-70-6	2.19	1-Heptanol
111-71-7	4.19	Heptanal
111-76-2	2.88	2-Butoxyethanol
111-77-3	2.88	2-(2-Methoxyethoxy) Ethanol
111-82-0	0.53	methyl dodecanoate {methyl laurate}
111-84-2	0.93	n-Nonane
111-87-5	1.99	1-Octanol
111-90-0	3.34	2-(2-Ethoxyethoxy) Ethanol
112-06-1	0.73	n-Heptyl Acetate
112-07-2	1.65	2-Butoxyethyl Acetate
112-14-1	0.64	n-Octyl Acetate
112-15-2	1.49	2-(2-Ethoxyethoxy) ethyl acetate
112-25-4	2.43	2-Hexyloxyethanol
112-27-6	3.41	triethylene glycol
112-30-1	1.22	1-decanol
112-34-5	2.87	2-(2-Butoxyethoxy)-Ethanol
112-35-6	2.59	2-[2-(2-Methoxyethoxy) ethoxy] ethanol
112-40-3	0.64	*n-Dodecane*
112-41-4	1.74	1-Dodecene
112-50-5	2.64	*2-[2-(2-Ethoxyethoxy) ethoxy] Ethanol*
112-59-4	2.00	2-(2-Hexyloxyethoxy) Ethanol
112-60-7	2.84	tetraethylene glycol
112-95-8	0.40	n-C20
115-07-1	11.57	Propene
115-10-6	0.93	Dimethyl Ether
115-11-7	6.31	Isobutene
115-18-4	5.08	2-Methyl-3-Butene-2-ol
115-77-5	2.42	pentaerythritol
116-09-6	3.08	Hydroxy Acetone
119-64-2	2.83	Tetralin
120-92-3	1.42	Cyclopentanone
122-99-6	3.61	2-Phenoxyethanol; Ethylene glycol phenyl ether
123-04-6		3-(Chloromethyl)-Heptane
123-17-1	1.55	Trimethylnonanolthreoerythro; 2,6,8-Trimethyl-4-nonanol
123-18-2	1.86	2,6,8-trimethyl-4-nonanone; Isobutyl heptyl ketone
123-38-6	7.88	Propionaldehyde
123-42-2	0.68	Diacetone Alcohol
123-51-3	2.73	isoamyl alcohol (3-methyl-1-butanol)
123-54-6	1.02	2,4-pentanedione
123-72-8	6.68	Butanal
123-86-4	0.88	*n-Butyl Acetate*
123-91-1	2.71	1,4-dioxane
123-92-2	1.18	*isoamyl acetate (3-methylbutyl acetate)*
124-04-9	3.37	adipic acid
124-10-7	0.47	methyl myristate {methyl tetradecanoate}
124-11-8	2.73	1-Nonene
124-13-0	3.62	Octanal
124-16-3	2.08	1-(butoxyethoxy)-2-propanol
124-17-4	1.36	2-(2-Butoxyethoxy) ethyl acetate
124-18-5	0.81	n-Decane

124-40-3	9.37	Dimethyl Amine
124-68-5	4.75	2-Amino-2-Methyl-1-Propanol
127-18-4	0.04	Perchloroethylene
127-91-3	3.28	b-Pinene
135-01-3	5.92	o-Diethyl Benzene
135-98-8	1.97	s-Butyl Benzene
137-32-6	2.60	2-methyl-1-butanol
140-88-5	8.73	Ethyl Acrylate
141-32-2	5.52	n-butyl acrylate
141-43-5	5.96	Ethanolamine
141-78-6	0.64	Ethyl Acetate
141-79-7	17.37	mesityl oxide (2-methyl-2-penten-4-one)
141-93-5	8.39	m-Diethyl Benzene
142-29-0	7.32	Cyclopentene
142-68-7	3.78	Tetrahydropyran
142-82-5	1.26	n-Heptane
142-92-7	0.87	n-Hexyl Acetate
142-96-1	3.14	Di-n-butyl Ether
143-13-5	0.58	n-Nonyl Acetate
143-22-6	2.21	2-[2-(2-Butoxyethoxy) ethoxy] Ethanol
144-19-4	1.76	2,2,4-Trimethyl-1,3-Pentanediol
149-57-5	3.49	2-Ethyl Hexanoic Acid
156-60-5	0.81	Trans-1,2-Dichloroethene
287-23-0	1.04	Cyclobutane
287-92-3	2.67	Cyclopentane
291-64-5	2.23	Cycloheptane
292-64-8	1.70	Cyclooctane
431-03-8	20.73	Biacetyl
463-82-1	0.69	Neopentane
464-06-2	1.32	2,2,3-Trimethyl Butane
496-11-7	3.16	Indan
503-17-3	16.32	2-Butyne
503-30-0	5.19	Trimethylene Oxide
503-74-2	4.26	3-Methylbutanoic acid
513-35-9	14.44	2-Methyl-2-Butene
526-73-8	11.25	1,2,3-Trimethyl Benzene
527-53-7	8.25	1,2,3,5 Tetramethyl Benzene
540-84-1	1.43	2,2,4-Trimethyl Pentane
540-88-5	0.20	t-Butyl Acetate
541-02-6		D5 Cyclosiloxane
542-92-7	7.55	Cyclopentadiene
544-76-3	0.50	n-C16
547-63-7	0.69	Methyl Isobutyrate
547-64-8	2.76	Methyl Lactate
554-12-1	0.71	Methyl Propionate
556-67-2		D4 Cyclosiloxane
558-37-2	6.02	3,3-Dimethyl-1-Butene
562-49-2	1.32	3,3-Dimethyl Pentane
563-45-1	6.95	3-Methyl-1-Butene
563-46-2	6.47	2-Methyl-1-Butene
563-78-0	4.75	2,3-Dimethyl-1-Butene

563-79-1	13.32	2,3-Dimethyl-2-Butene
563-80-4	1.64	Methyl Isopropyl Ketone
565-59-3	1.53	2,3-Dimethyl Pentane
565-75-3	1.22	2,3,4-Trimethyl Pentane
565-80-0	1.61	Di-Isopropyl Ketone
581-40-8	5.54	2,3-Dimethyl Naphthalene
584-02-1	1.73	3-Pentanol
584-03-2	2.20	1,2-Butandiol
584-84-9	-0.13	2,4-Toluene Diisocyanate
584-94-1	1.32	2,3-Dimethyl Hexane
589-34-4	1.84	3-Methyl Hexane
589-43-5	1.79	2,4-Dimethyl Hexane
589-53-7	1.46	4-Methyl Heptane
589-62-8	3.04	4-Octanol
589-81-1	1.33	3-Methyl Heptane
590-01-2	0.87	Butyl Propionate
590-18-1	13.22	cis-2-Butene
590-35-2	1.21	2,2-Dimethyl Pentane
590-73-8	1.12	2,2-Dimethyl Hexane
590-86-3	5.47	3-Methylbutanal (Isovaleraldehyde)
591-21-9	1.69	1,3-Dimethyl Cyclohexane
591-47-9	4.44	4-Methyl Cyclohexene
591-49-1	7.70	1-Methyl Cyclohexene
591-76-4	1.36	2-Methyl Hexane
591-78-6	3.53	Methyl n-Butyl Ketone
592-13-2	1.66	2,5-Dimethyl Hexane
592-27-8	1.18	2-Methyl Heptane
592-41-6	6.12	1-Hexene
592-43-8	8.35	2-Hexenes
592-76-7	4.20	1-Heptene
592-84-7	0.94	n-Butyl Formate
593-45-3	0.44	n-C18
594-56-9	4.59	2,3,3-trimethyl-1-Butene
594-82-1	0.44	2,2,3,3-Tetramethyl Butane
598-98-1	0.39	Methyl Pivalate
611-14-3	6.61	o-Ethyl Toluene
616-38-6	0.06	Dimethyl Carbonate
620-14-4	9.37	m-Ethyl Toluene
622-58-2	0.94	Para Toluene Isocyanate
622-96-8	3.75	p-Ethyl Toluene
623-42-7	1.16	Methyl Butyrate
623-84-7	0.94	1,2-Propylene glycol diacetate
624-41-9	1.17	2-methyl-1-butyl acetate
624-54-4	0.79	n-pentyl propionate
624-64-6	13.90	trans-2-Butene
624-91-9		Methyl Nitrite
625-27-4	11.87	2-Methyl-2-Pentene
625-54-7	3.86	Ethyl Isopropyl Ether
625-55-8	0.42	Isopropyl Formate
626-93-7	2.45	2-Hexanol
627-20-3	10.23	cis-2-Pentene

627-93-0	1.94	Dimethyl Adipate
628-28-4	3.63	Methyl n-Butyl Ether
628-55-7	1.29	Di-Isobutyl Ether
628-63-7	0.94	Amyl Acetate
628-81-9	3.84	Ethyl n-Butyl Ether
629-14-1	2.84	ethylene glycol diethyl ether; 1,2-diethoxyethane
629-50-5	0.60	n-Tridecane
629-59-4	0.56	n-Tetradecane
629-62-9	0.53	n-Pentadecane
629-78-7	0.47	n-C17
629-92-5	0.42	n-C19
629-94-7	0.38	n-C21
629-97-0	0.36	n-C22
630-08-0	0.06	Carbon Monoxide
630-19-3	5.40	2,2-Dimethylpropanal (pivaldehyde)
637-92-3	2.11	Ethyl t-Butyl Ether
646-04-8	10.23	trans-2-Pentene
646-06-0	5.47	1,3-dioxolane
690-08-4	6.92	Trans 4,4-dimethyl-2-Pentene
690-93-7	5.90	Trans 2,2-Dimethyl 3-Hexene
691-37-2	6.21	4-Methyl-1-Pentene
692-70-6	5.37	Trans 2,5-Dimethyl 3-Hexene
693-54-9	1.04	2-Decanone
693-65-2	2.60	Di-n-Pentyl Ether
693-89-0	13.44	1-Methyl cyclopentene
760-20-3	6.17	3-Methyl-1-Pentene
760-21-4	5.01	2-Ethyl-1-Butene
763-29-1	5.15	2-Methyl-1-Pentene
763-69-9	3.59	Ethyl 3-Ethoxy Propionate
764-97-6	4.18	Trans-5-Undecene
770-35-4	1.73	1-phenoxy-2-propanol
821-55-6	1.28	2-Nonanone
821-95-4	1.93	1-Undecene
871-83-0	0.83	2-Methyl Nonane
872-05-9	2.25	1-Decene
872-50-4	2.55	N-Methyl-2-Pyrrolidone
919-94-8	2.03	4,4-Dimethyl-3-oxahexane
925-54-2	3.97	2-methyl-hexanal
926-82-9	1.61	3,5-Dimethyl Heptane
994-05-8	2.14	Methyl t-Amyl Ether
1002-43-3	0.68	3-Methyl Undecane
1004-29-1	2.49	2-Butyl Tetrahydrofuran
1067-20-5	1.34	3,3-Diethyl Pentane
1069-53-0	1.31	2,3,5-Trimethyl Hexane
1119-40-0	0.50	Dimethyl Glutarate
1120-21-4	0.72	n-Undecane
1120-36-1	1.38	1-Tetradecene
1191-95-3	0.68	Cyclobutanone
1319-77-3	2.34	C7 Alkyl Phenols
1320-67-8	4.01	3-methoxy-1-propanol
1321-60-4	2.17	trimethylcyclohexanol

1321-94-4	4.61	Methyl Naphthalenes
1330-20-7	7.48	C8 Disubstituted Benzenes
1559-34-8	1.86	3,6,9,12-Tetraoxahexadecan-1-ol
1559-35-9	1.68	2-(2-Ethylhexyloxy) Ethanol
1569-01-3	2.84	1-Propoxy-2-Propanol (Propylene glycol n-propyl ether)
1569-02-4	3.23	1-Ethoxy-2-Propanol
1589-47-5	3.00	2-Methoxy-1-Propanol
1632-70-8	0.69	5-Methyl Undecane
1634-04-4	0.78	Methyl t-Butyl Ether
1640-89-7	2.25	Ethyl Cyclopentane
1674-10-8	6.66	1,2-Dimethyl Cyclohexene
1678-91-7	1.72	Ethylcyclohexane
1678-92-8	1.45	Propyl Cyclohexane
1678-93-9	1.05	Butyl Cyclohexane
1678-99-5	1.31	1,3-Diethyl-Cyclohexane
1679-00-1	1.46	1,4-Diethyl-Cyclohexane
1795-15-9	0.58	Octyl Cyclohexane
1795-16-0	0.48	Decyl Cyclohexane
1871-57-4	3.13	2-(Cl-methyl)-3-Cl-Propene
2040-96-2	1.89	Propyl Cyclopentane
2050-01-3	0.88	Isoamyl Isobutyrate
2051-30-1	1.24	2,6-Dimethyl Octane
2213-23-2	1.46	2,4-Dimethyl Heptane
2216-32-2	1.42	4-Ethyl Heptane
2216-34-4	1.05	4-Methyl Octane
2437-56-1	1.52	1-Tridecene
2453-00-1	2.13	1,3-Dimethyl Cyclopentane
2517-43-3	0.97	3-Methoxy-1-Butanol
2550-21-2	2.81	3-Methyl-2-Hexanone
2807-30-9	3.50	2-Propoxyethanol
2847-72-5	0.78	4-Methyl Decane
2882-96-4	0.48	3-Methyl Pentadecane
2883-02-5	0.52	Nonyl Cyclohexane
2918-23-2	5.56	hydroxypropyl acrylate
3073-66-3	1.34	1,1,3-Trimethyl Cyclohexane
3178-29-8	1.22	4-Propyl Heptane
3221-61-2	0.94	2-Methyl Octane
3387-41-5	3.66	Sabinene
3522-94-9	1.31	2,2,5-Trimethyl Hexane
3638-35-5	1.51	Isopropyl Cyclopropane
3683-22-5	7.82	Trans 4-Methyl-2-Hexene
3728-56-1	1.59	1-Ethyl-4-Methyl Cyclohexane
4032-94-4	1.07	2,4-Dimethyl Octane
4050-45-7	8.35	Trans-2-Hexene
4128-31-8	2.13	2-Octanol
4170-30-3	9.96	Crotonaldehyde
4292-75-5	0.72	Hexyl Cyclohexane
4292-92-6	0.89	Pentyl Cyclohexane
5131-66-8	2.73	n-Butoxy-2-Propanol (Propylene Glycol n-Butyl Ether)
5617-41-4	0.63	Heptyl Cyclohexane
5878-19-3	2.13	Methoxy Acetone

5911-04-6	0.86	3-Methyl Nonane
5989-27-5	3.99	d-Limonene
6032-29-7	1.73	2-Pentanol
6165-40-8	0.49	7-Methyl Pentadecane
6224-52-8	0.66	3,8-Diethyl Decane
6418-41-3	0.55	3-Methyl Tridecane
6482-34-4	1.04	Diisopropyl Carbonate
6881-94-3	2.97	2-(2-Propoxyethoxy) ethanol
6915-15-7	7.51	malic acid
6920-22-5	2.73	1,2-Dihydroxy Hexane
6938-94-9	1.42	diisopropyl adipate
7145-20-2	10.40	2,3-Dimethyl-2-Hexene
7206-16-8	3.70	Trans-5-Dodecene
7212-53-5	1.95	5-methyl-1-heptanol
7379-12-6	1.77	2-Methyl-3-Hexanone
7433-78-5	4.83	Cis-5-Decene
7642-09-3	8.13	Cis-3-Hexene
7642-10-6	6.88	Cis-3-Heptene
7642-15-1	5.86	Cis-4-Octene
7688-21-3	8.35	Cis-2-Hexene
10143-23-4	2.51	dimethylpentanol (2,3-dimethyl-1-pentanol)
10405-85-3	5.24	Trans-4-Nonene
10574-36-4	12.84	Cis-3-Methyl-2-Pentene
13151-34-3	0.74	3-Methyl Decane
13254-34-7	1.07	dimethylheptanol (2,6-dimethyl-2-heptanol)
13269-52-8	8.07	Trans-3-Hexene
13286-72-1	0.59	3,9-Diethyl Undecane
13287-21-3	0.59	6-Methyl Tridecane
13360-61-7	1.27	1-Pentadecene
13466-78-9	3.21	3-Carene
13588-28-8	2.70	Dipropylene Glycol Methyl Ether isomer (2-[2-methoxypropoxy]-1-propanol)
14638-54-1	0.94	2,4,6,8-Tetramethyl Nonane
14686-13-6	7.26	Trans-2-Heptene
14686-14-7	6.88	Trans-3-Heptene
14850-23-8	5.83	Trans-4-Octene
14919-01-8	6.06	Trans-3-Octene
15764-24-6	2.75	dipropylene glycol ethyl ether
16580-24-8	1.23	1-Methyl-3-Isopropyl Cyclohexane
17301-28-9	0.79	3,6-Dimethyl Undecane
17301-94-9	0.96	4-Methyl Nonane
17302-28-2	0.92	2,6-Dimethyl Nonane
17312-53-7	0.85	3,6-Dimethyl Decane
17312-57-1	0.61	3-Methyl Dodecane
17453-93-9	0.62	5-Methyl Dodecane
18435-22-8	0.51	3-Methyl Tetradecane
18491-15-1	0.91	1-Hydroxy-2,2,4-Trimethylpentyl-3-Isobutyrate
19398-77-7	1.18	3,4-Diethyl Hexane
19398-89-1	4.44	Trans-4-Decene
20296-29-1	2.53	3-Octanol
20710-38-7	13.54	Trans 3-Methyl-2-Hexene

23051-84-5	3.34	Trans-5-Tridecene
23305-64-8	2.43	2-[2-(2-Propoxyethoxy) ethoxy] Ethanol
23783-42-8	2.13	2,5,8,11-Tetraoxatridecan-13-ol
25265-77-4	0.88	Texanol isomers
25339-17-7	1.21	8-Methyl-1-Nonanol (Isodecyl Alcohol)
25498-49-1	1.88	Tripropylene Glycol Monomethyl Ether
25551-13-7	9.90	C9 Trisubstituted Benzenes
26471-62-5		Toluene Diisocyanate (mixed isomers)
26730-16-5	0.55	6-Methyl Tetradecane
29911-28-2	1.96	glycol ether dpnb {1-(2-butoxy-1-methylethoxy)-2-propanol}
30136-13-1	3.84	n-propoxypropanol
39762-40-8	0.53	1-Methyl-4-Nonyl Cyclohexane
40364-84-9	6.56	Hydroxy Methacrolein
40649-36-3	2.08	4-propyl cyclohexanone
41446-66-6	3.03	Trans-5-Tetradecene
51729-83-0	0.69	Methyl Isopropyl Carbonate
56539-66-3	1.73	3 methoxy -3 methyl-Butanol
57018-52-7	1.70	1-tert-Butoxy-2-Propanol
59643-70-8	3.90	3,4-Diethyl-2-Hexene
61168-10-3	3.39	1-nonene-4-one
61868-54-0	1.26	2,3,4,6-Tetramethyl Heptane
61869-02-1	1.18	3,5-Diethyl Heptane
62183-94-2	1.07	2,6-Diethyl Octane
62199-32-0	1.06	2,3,5,7-Tetramethyl Octane
62238-33-9	0.92	1-Ethyl-2-Propyl Cyclohexane
70657-70-4	1.12	2-Methyoxy-1-propyl Acetate
74392-33-9	2.78	Trans-5-Pentadecene
75736-67-3	0.80	1-Methyl-4-Pentyl Cyclohexane
82144-67-0	0.71	3,7-Dimethyl Dodecane
84540-57-8	1.97	methoxypropanol acetate
88917-22-0	1.49	Dipropylene glycol methyl ether acetate
89399-28-0	2.09	2-methoxy-1-(2-methoxy-1-methylethoxy)-propane
92031-93-1	0.67	1-Methyl-2-Hexyl-Cyclohexane
94023-15-1	1.79	2-tert-Butoxy-1-Propanol
111823-35-9	3.26	3-Methyl-2-Isopropyl-1-Butene
164259-42-1	1.08	1,3-Diethyl-5-Methyl Cyclohexane
164259-43-2	1.03	1,3,5-Triethyl Cyclohexane
175032-36-7	0.55	4,8-Dimethyl Tetradecane
205324-73-8	0.58	trans 1-Methyl-4-Heptyl Cyclohexane

Appendix G

Diurnal Emissions Comparison

The difference in permeation measured when Fuel B (with ethanol) was tested, compared to Fuel A is presented in Table 20. The average permeation increased on all ten rigs when the fuel was switched from the MTBE oxygenate fuel (Fuel A) to the ethanol oxygenate fuel (Fuel B). The increase ranged from 0.34 g/day to 2.71 g/day, with an average increase of 1.40 g/day.

Table 20
Comparison of Diurnal Permeation Rates Between Fuel A and Fuel B

			Increase: Fuel A to Fuel B	
Rig	Vehicle	Tank	g/day	%
1	2001 Toyota Tacoma	15.8 gal - Metal	0.52	216.2
2	2000 Honda Odyssey	20.0 gal - Plastic	0.79	124.6
3	1999 Toyota Corolla	13.2 gal - Metal	1.08	374.3
4	1997 Chrysler Town & Country	20.0 gal - Plastic	1.62	258.9
5	1995 Ford Ranger	16.5 gal - Plastic	2.45	26.6
6	1993 Chevrolet Caprice Classic	23.0 gal - Plastic	0.34	7.4
7	1991 Honda Accord LX	17.0 gal - Metal	1.02	82.0
8	1989 Ford Taurus GL	16.0 gal - Metal	1.67	173.7
9	1985 Nissan Sentra	13.2 gal - Metal	2.71	138.0
10	1978 Olds Cutlass Supreme	18.1 gal - Metal	1.82	94.7
		Average	**1.40**	**149.7**

The difference in permeation measured when Fuel B (with ethanol) was tested, compared to Fuel C (no oxygenate) is presented in Table 21. The increase ranged from -0.15 g/day to 2.90 g/day, with an average increase of 1.10 g/day.

Table 21
Comparison of Diurnal Permeation Rates Between Fuel B and Fuel C

			Increase: Fuel C to Fuel B	
Rig	Vehicle	Tank	g/day	%
1	2001 Toyota Tacoma	15.8 gal - Metal	0.54	241.7
2	2000 Honda Odyssey	20.0 gal - Plastic	0.85	145.2
3	1999 Toyota Corolla	13.2 gal - Metal	1.04	314.6
4	1997 Chrysler Town & Country	20.0 gal - Plastic	1.12	98.7
5	1995 Ford Ranger	16.5 gal - Plastic	-0.15	-1.3
6	1993 Chevrolet Caprice Classic	23.0 gal - Plastic	1.18	31.7
7	1991 Honda Accord LX	17.0 gal - Metal	0.34	17.8
8	1989 Ford Taurus GL	16.0 gal - Metal	1.80	218.2
9	1985 Nissan Sentra	13.2 gal - Metal	2.90	163.6
10	1978 Olds Cutlass Supreme	18.1 gal - Metal	1.43	62.3
		Average	**1.10**	**129.3**

Finally, a comparison of the permeation results from Fuel C compared to Fuel A is offered in Table 22. The increase ranged from -0.84 g/day to 2.60 g/day, with an average increase of 0.30 g/day.

Table 22
Comparison of Diurnal Permeation Rates Between Fuel A and Fuel C

Rig	Vehicle	Tank	Increase: Fuel A to Fuel C g/day	Increase: Fuel A to Fuel C %
1	2001 Toyota Tacoma	15.8 gal - Metal	-0.02	-7.5
2	2000 Honda Odyssey	20.0 gal - Plastic	-0.05	-8.4
3	1999 Toyota Corolla	13.2 gal - Metal	0.04	14.4
8	1989 Ford Taurus GL	16.0 gal - Metal	-0.13	-14.0
9	1985 Nissan Sentra	13.2 gal - Metal	-0.19	-9.7
		Group Average	-0.07	-5.04
4	1997 Chrysler Town & Country	20.0 gal - Plastic	0.51	80.6
5	1995 Ford Ranger	16.5 gal - Plastic	2.60	28.3
6	1993 Chevrolet Caprice Classic	23.0 gal - Plastic	-0.84	-18.4
7	1991 Honda Accord LX	17.0 gal - Metal	0.67	54.4
10	1978 Olds Cutlass Supreme	18.1 gal - Metal	0.38	20.0
		Group Average	0.66	33.0
		Overall Average	**0.30**	**14.0**

Table 22 shows two groups of rigs – the upper set contains test results where the difference between Fuel A and Fuel C was minor (average of -0.07 g/day, and 5.0% of level). The lower set indicated a larger difference (0.66 g/day and 33%) between the diurnal permeation results of the two fuels.

Appendix H

Individual Laboratory Fuel Inspections

CRC E-65 Permeation Study Individual Laboratory Fuel Inspections

Inspection	Units	Fuel A – CARB 2 MTBE					Fuel B -- CARB 3 Ethanol					Fuel C -- CARB 2 Non-Oxy				
Laboratory		A	B	C	D	Average	A	B	C	D	Average	A	B	C	D	Average
API Gravity	°API	58.8	58.7	58.7	58.9	58.8	58.2	58.1	58.1	58.2	58.2	61.1	60.9	60.9	61.1	61.0
Relative Density	60/60°F	0.7436	0.7440	0.7441	0.7432	0.7437	0.7459	0.7463	0.7463	0.7459	0.7461	0.7347	0.7354	0.7356	0.7349	0.7
DVPE	psi	7.10	6.88	6.98	7.24	7.1	7.12	7.10	6.98	7.28	7.12	7.06	6.93	6.95	7.16	7.0
Oxygenates--D 4815																
MTBE	vol%	9.7	9.88	9.85	10.1	9.88	<0.1	0.04	0.0	<0.1	<0.1	0.1	0.07	0.0	0.0	0.04
TAME	vol%	1.2	1.42	0.95	0.9	1.13	<0.1	0.00	0.0	<0.1	<0.1	0.1	0	0.0	0.0	0.02
EtOH	vol%	0.0	0.00	0.00	0.0	0.00	5.4	5.61	5.48	5.3	5.5	<0.1	0	0.0	0.0	0.0
O2	wt%	1.96	2.03	1.95	1.99	1.98	2.01	2.08	2.03	1.96	2.02	0.02	0.01	0.0	0.0	0.0
FIAM Corrected--D 1319																
Aromatics	vol%	22.6	22.0	24.15	-	22.9	27.9	24.0	25.7	-	25.9	27.6	26.2	26.3	-	26.7
Olefins	vol%	5.8	4.4	4.69	-	5.0	7.3	4.9	5.2	-	5.8	6.7	5.8	5.4	-	6.0
Saturates	vol%	60.7	62.3	60.36	-	61.1	59.4	65.5	63.6	-	62.8	65.5	68.0	68.3	-	67.3
Oxygenates	vol%	10.9	11.3	10.8	11.0	11.0	5.4	5.65	5.48	5.3	5.5	0.2	0.07	0.0	0	0.07
Aromatics--D 5580																
Benzene	vol%	0.52	-	0.53	0.55	0.53	0.70	-	0.71	0.74	0.72	0.75	-	0.72	0.72	0.73
Toluene	vol%	8.33	-	8.27	8.17	8.26	7.02	-	6.79	6.90	6.90	8.59	-	8.44	8.36	8.46
Ethylbenzene	vol%	0.98	-	0.83		0.91	1.20	-	1.03		1.12	1.54	-	1.35		1.45
p/m-Xylene	vol%	4.00	-	3.63	6.54[a]	3.82	5.12	-	4.71	8.2[a]	4.91	5.84	-	5.57	9.66[a]	5.71
o-Xylene	vol%	1.45	-	1.38		1.42	1.77	-	1.75		1.76	2.12	-	2.10		2.11
C9+	vol%	8.91	-	-	8.26	8.59	10.28	-	-	9.98	10.13	8.36	-	-	6.88	7.62
Total	vol%	24.31	-	-	24.20	24.26	26.08	-	-	26.40	26.24	27.20	-	-	27.20	27.20

[a] C8 aromatics

Appendix H

Individual Laboratory Fuel Inspections (Cont)

CRC E-65 Permeation Study Individual Laboratory Fuel Inspections

Inspection	Units	Fuel A – CARB 2 MTBE					Fuel B – CARB 3 Ethanol					Fuel C – CARB 2 Non-Oxy				
Laboratory		A	B	C	D	Average	A	B	C	D	Average	A	B	C	D	Average
D 86 Distillation																
IBP	°F	99.5	101.3	101.8	100.1	100.7	111.3	110.2	105.26	107.2	108.5	101.1	100.7	102.0	100.2	101.0
5% Evaporated	°F	126.3	126.5	128.8	122.7	126.1	130.4	128.9	127.76	127.9	128.7	129.5	130.6	126.1	125.7	128.0
10% Evaporated	°F	136.4	136.0	137.5	133.2	135.8	135.3	133.9	132.62	133.5	133.8	137.6	138.5	135.0	134.2	136.3
20% Evaporated	°F	148.4	147.7	149	146	147.8	140.9	139.3	140	140.2	140.1	149.5	149.4	146.7	146.2	147.9
30% Evaporated	°F	161.6	160.7	162	158.6	160.7	160.8	156.8	152.06	152	155.4	162.8	161.7	158.7	158.4	160.4
40% Evaporated	°F	177.8	175.6	177.4	175.1	176.5	186.9	184.8	181.94	184.3	184.5	178.1	176.5	173.5	173.7	175.4
50% Evaporated	°F	196.8	195.1	196.9	194.2	195.7	204.6	203.4	201.2	201.8	202.8	195.9	194.4	190.8	191.2	193.1
60% Evaporated	°F	221.0	218.5	219.9	217.5	219.2	220.1	219.0	216.32	218.1	218.4	216.6	214.4	211.1	211.1	213.3
70% Evaporated	°F	245.3	242.6	244.4	242.6	243.7	237.3	236.2	234.86	234.7	235.8	239.7	237.6	233.4	234.5	236.3
80% Evaporated	°F	271.4	269.8	270	269	270.0	262.2	261.1	260.24	261.1	261.2	265.1	263.4	260.1	261	262.4
90% Evaporated	°F	309.5	308.8	308.3	308.7	308.8	304.7	303.4	302.54	305.4	304.0	301.2	298.4	295.3	296.8	297.9
95% Evaporated	°F	334.7	333.3	332.6	333.1	333.4	332.6	333.9	328.64	333.5	332.2	330.9	323.9	320.4	320.7	324.0
EP	°F	375.6	370.6	369.9	375.9	373.0	391.8	394.6	369.68	386.8	385.7	368.9	374.7	355.8	365.8	366.3
Recovery	vol%	97.1	97.3	98.3	96.7	97.4	98.7	98.2	97.7	97.9	98.1	97.7	98.2	97.6	97.9	97.9
Residue	vol%	1.2	1.2	0.9	2.1	1.4	1.0	0.8	1.1	1	1.0	1.0	0.7	0.9	1.1	0.9
Loss	vol%	1.7	1.5	0.8	0.9	1.2	0.3	1.0	1.2	1	0.9	1.3	1.1	1.5	0.9	1.2
Gum																
Unwashed	mg/100ml	17.6	-	-	16	16.8	20.0	-	-	18.2	19.1	20.0	-	-	17	18.5
Washed	mg/100ml	1.0	-	-	1	1.0	0.0	-	-	1	0.5	0.0	-	-	1.2	0.6
Sulfur	ppm	25.0	27.0	-	25.0	25.7	14.0	16.0	-	14.0	14.7	18.0	18.0	-	17.0	17.7

DEMONSTRATION THAT THE U.S. ENVIRONMENTAL PROTECTION AGENCY MUST GRANT CALIFORNIA A WAIVER FROM THE FEDERAL REFORMULATED GASOLINE OXYGEN MANDATE ON REMAND FROM THE U.S. COURT OF APPEALS FOR THE NINTH CIRCUIT

December 2003

SUMMARY

The new data and the discussion presented in the sections that follow lead to the conclusion that, in California, the federal RFG oxygen mandate results in increases in the combined of NOx and VOC emissions, and these emission increases prevent or interfere with attainment of the PM_{10} and $PM_{2.5}$ NAAQS. As shown in Section II, attaining and maintaining the NAAQS for PM_{10} and $PM_{2.5}$ is important to the health and welfare of the people of California.

In addition, this analysis also clearly demonstrates that the federal RFG oxygen mandate additionally prevents or interferes with attainment of the ozone NAAQS in the state's ozone nonattainment areas. In all scenarios the federal RFG oxygen mandate shows substantial increases in the combined emissions of NOx and VOC – the two principal precursors of ozone.

Based on the data and analysis now available, California has adequately demonstrated that a waiver will assist the State's efforts to attain and maintain the NAAQS for ozone. Under these circumstances, where it has been shown that the federal RFG oxygen mandate clearly interferes with attainment of the PM_{10} and $PM_{2.5}$ NAAQS and likely interferes with attainment of the ozone NAAQS, the Clean Air Act provides no basis for U.S. EPA to deny a waiver based on the unlikely possibility that a waiver might hinder ozone attainment.

U.S. EPA should not ignore the fact that the State of California, the ARB, and the South Coast Air Quality Management District have all concluded that a waiver is needed to avoid the emissions increases and degradation of air quality that results in California from the federal RFG oxygen mandate. Section 211(c)(4)(B) of the Clean Air Act recognizes California's longstanding expertise in regulating motor vehicle fuels to reduce emissions – and the unique air quality problems the State faces – by making California the only state to enjoy a blanket exemption from federal preemption of its motor vehicle fuels regulations. The state has been a pioneer in reducing emissions through standards for gasoline, and was already limiting summertime RVP in the early 1970's. In this context, U.S. EPA must give some deference to California's determinations on the air quality impacts of the oxygen mandate.

Finally, in addition to the technical facts that support granting the waiver U.S. EPA should also recognize the substantial cost savings to Californians that will accompany the emission reductions that result from the waiver. This is not the normal case where emission reductions come at a significant cost. The emissions reductions will instead come with an actual cost savings to the people of California – estimated several hundreds of millions of dollars annually. The Court requires that U.S. EPA reconsider this matter. Given the facts and analysis now available we believe that U.S. EPA accordingly has only one justifiable option at this time: to respond to the Court's remand by granting the waiver.

I. BACKGROUND – THE WAIVER DENIAL AND THE NINTH CIRCUIT COURT OF APPEALS DECISION

Approximately 80 percent of the gasoline sold in California is now subject to the federal Reformulated Gasoline (RFG) requirements. Under section 211(k)(2)(B) of the Clean Air Act (CAA), one of the requirements for federal RFG is that it must contain at least 2.0 weight percent (wt.%) oxygen, which is added to gasoline by an oxygenate such as Methyl Tertiary-Butyl Ether (MTBE) or ethanol. However, in that subsection Congress expressly authorized the United States Environmental Protection Agency (U.S. EPA) to grant a waiver from the oxygen mandate for federal RFG if compliance with the requirement in an area "prevent[s] or interfere[s] with the attainment by the area of a national ambient air quality standard [NAAQS]."

California originally requested the waiver of the federal RFG oxygen mandate in an April 12, 1999 letter, and the Air Resources Board (ARB) made several supplemental submittals. The U.S. EPA deemed California's waiver application complete in a February 14, 2000 letter from Assistant Administrator Robert Perciasepe to California Environmental Protection Agency (Cal-EPA) Secretary Winston Hickox. The justification for a waiver results from the fact that refiners producing gasoline for the federal RFG areas in California must meet the California Reformulated Gasoline (CaRFG) standards as well as the federal RFG standards. The U.S. EPA ultimately agreed with the ARB's conclusion that – because of the way the California Phase 3 Reformulated Gasoline (CaRFG3) Predictive Model works and the effect of gasoline's oxygen content on oxides of nitrogen (NOx) emissions – the CaRFG3 produced by refiners when they also have to meet the federal RFG oxygen mandate will result in greater NOx emissions than will be the case with a waiver. NOx emissions contribute to both ozone and particulate matter (PM) pollution. Emissions of volatile organic compounds (VOC) and to a much less extent emissions of carbon monoxide (CO) interact in the atmosphere with nitrogen dioxide (NO_2) to form elevated levels of ozone.

In its waiver analysis, the U.S. EPA concluded that along with increasing NOx emissions in California, the federal oxygen mandate reduces CO emissions and there is uncertainty whether it reduces or increases VOC emissions. The U.S. EPA interpreted CAA section 202(k)(2)(B) to mean that the agency should grant a waiver only if it is "clearly demonstrated" that the waiver will aid in attainment of a NAAQS, <u>and</u> will not hinder the attainment of the ambient standards for any other pollutants.[1] The agency decided that the uncertainty regarding the effects of a waiver on attaining the ozone

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[1] U.S. EPA's June 2001 Technical Support Document (TSD), Appendix A, page 145.

standard did not justify issuance of a waiver on the basis of impacts on ozone pollution. The U.S. EPA further concluded that once it found it should not issue the waiver based on impacts on ozone the agency did not need to further consider whether the effect of the oxygen mandate on attainment of the PM NAAQS justified a waiver. The Ninth Circuit Court of Appeals (the Court) concluded that the U.S. EPA abused its discretion by refusing to evaluate the effect that an oxygen waiver would have on California's efforts to comply with the PM NAAQS. The Court stated, "By ignoring the evidence concerning the effects of a waiver on PM, the U.S. EPA refused to make the statutorily-directed determination whether denial of the State's waiver request would interfere with attainment of a NAAQS."[2] The Court explained:

> The EPA's current approach also cripples the goals of the CAA when, as in the current situation, the effects of a waiver on one NAAQS are merely uncertain, not necessarily negative. Although California was unable to clearly demonstrate that the oxygen requirement would interfere with ozone standards, the EPA found no conclusive evidence that a waiver would be harmful to ozone. The effects of a waiver on ozone are uncertain at worst. The EPA nevertheless refused to consider the significance of the PM evidence. It adhered to this refusal even though the benefit of a waiver to the PM NAAQS could conceivably outweigh the uncertain effects of that waiver on ozone levels.[3]

The Court vacated the Administrator's June 12, 2001 denial of our waiver request, and remanded the matter to the U.S. EPA with instructions to review the request with full consideration of the effects of a waiver on both the ozone and the PM NAAQS.

II. ATTAINING AND MAINTAINING THE NAAQS FOR PM_{10} AND $PM_{2.5}$ IS IMPORTANT TO THE HEALTH AND WELFARE OF THE PEOPLE OF CALIFORNIA

The U.S. EPA administers two primary NAAQS for particulate matter with a nominal diameter of 10 microns or less (PM_{10}) – an annual standard of 50 microns per cubic meter ($\mu g/m^3$), and a 24-hour standard of 150 $\mu g/m^3$. The agency also administers two primary NAAQS for particulate matter with a nominal diameter of 2.5 microns or less ($PM_{2.5}$) – an annual standard of 15.0 $\mu g/m^3$, and a 24-hour standard of 65 $\mu g/m^3$.[4]

The federal RFG oxygen mandate applies to all gasoline sold in the following areas of California: (1) Los Angeles, Ventura, Orange, and most of San Bernardino and Riverside Counties (which include the South Coast Air Basin, or SCAB), (2) San Diego County, (3) the Sacramento Metro nonattainment area, and (4) the San Joaquin Valley nonattainment area (which includes the San Joaquin Valley Air Basin, or SJVAB). About 80 percent of the state's gasoline is sold in these areas.

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[2] 336 F.3d at 977.

[3] *Id.*

[4] 40 Code of Federal Regulations (CFR) §§ 50.6 and 50.7.

The South Coast Air Basin and the San Joaquin Valley Air Basin are both currently designated by U.S. EPA as "serious" nonattainment for the federal PM_{10} standard, and Sacramento County is designated as "moderate" nonattainment.[5] San Diego County was among the five areas in the nation recently identified by the U.S. EPA as having "a significant risk of failing to attain and maintain the PM_{10} NAAQS without further reductions in emissions."[6]

The U.S. EPA has not yet made nonattainment designations for the $PM_{2.5}$ standard, but has announced its intention to do so in 2004.[7] Monitoring data from 2000-2002 in California indicates that the South Coast and San Joaquin Valley air basins meet the criteria for nonattainment designations for both the 24-hour and annual $PM_{2.5}$ NAAQS, and San Diego County meets the criteria for a nonattainment designation for the annual $PM_{2.5}$ NAAQS.[8] In both the South Coast and the San Joaquin Valley, far more sites exceed the annual and 24-hour $PM_{2.5}$ NAAQS than is the case with the PM_{10} NAAQS.[9] In addition, relatively high 24-hour measurements of $PM_{2.5}$ are found in the Sacramento Valley Air Basin.

The U.S. EPA clearly recognizes that attainment and maintenance of the PM NAAQS is important to public health. In 2000, the agency adopted its "Tier 2" motor vehicle emissions standards, which primarily target NOx reductions from the same light-duty vehicles whose NOx emissions are increased by the federal RFG oxygen mandate. In the Preamble to the final rule, the U.S. EPA identified the harmful effects of exposure to elevated levels of PM:

> Particulate matter, like ozone, has been linked to a range of serious respiratory health problems. Scientific studies suggest a likely causal role of ambient particulate matter in contributing to a series of health effects. The key health effects categories associated with particulate matter include premature mortality, aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days), changes in lung function and increased respiratory symptoms, changes in lung tissues and structure, and altered respiratory defense mechanisms. PM also causes damage to materials and soiling. It is a major cause of substantial visibility impairment in many parts of the U.S.
>
> Motor vehicle particle emissions and the particles formed by the transformation of motor vehicle gaseous emissions tend to be in the fine particle range. Fine particles are a special health concern because they

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[5] 40 CFR § 81.305. The South Coast and San Joaquin Valley exceed both the annual and 24-hour $PM10_{10}$ standards, while Sacramento has exceeded the 24-hour $PM10_{10}$ standard.

[6] 65 Federal Register (FR) 6698, 6719 (Feb. 10, 2000).

[7] 4/1/03 Memorandum from U.S. EPA Assistant Administrator Jeffrey R. Holmstead re Designations for the Fine Particulate National Ambient Air Quality Standards.

[8] Area Status for $PM_{2.5}$ National Ambient Air Quality Standards, 6/6/03 draft.

[9] For instance, in 2002 15 out of the 16 sites in the South Coast exceeded the annual $PM_{2.5}$ NAAQS, as all 11 of the sites in the San Joaquin Valley. See Attachment 1.

easily reach the deepest recesses of the lungs. Scientific studies have linked fine particles (alone or in combination with other air pollutants), with a series of significant health problems, including premature death; respiratory related hospital admissions and emergency room visits; aggravated asthma; acute respiratory symptoms, including aggravated coughing and difficult or painful breathing; chronic bronchitis; and decreased lung function that can be experienced as shortness of breath.[10]

III. THE FEDERAL RFG OXYGEN MANDATE CLEARLY PREVENTS AND INTERFERES WITH ATTAINMENT OF THE NATIONAL AMBIENT AIR QUALITY STANDARDS FOR PM_{10} AND $PM_{2.5}$ IN CALIFORNIA'S FEDERAL RFG AREAS

A. The U.S. EPA Has Already Determined That the Federal RFG Oxygen Mandate Results in a Substantial Increase in NOx Emissions in California

Almost one-half of the U.S. EPA's June 2001 TSD (Section III A and B, pages 18-78) addressed the impact of the federal RFG oxygen requirement on NOx emissions in California. The agency's analysis recognized California's unique setting in which refiners will have to meet the CaRFG3 standards as well as the federal RFG standards. Central to the agency's ultimate conclusions on NOx impacts was a set of 12 potential comparison scenarios described on pages 74-77 of the TSD. Table 31 of the TSD shows that in every one of the twelve scenarios, the federal RFG oxygen mandate results in increases in NOx emissions in the South Coast Air Basin. Those NOx emission increases are substantial – ranging from 5 tons per day (tpd) to 11 tpd, with an average increase of 7 tpd. This average increase is comparable to the NOx emissions from fuel combustion in all electric utility power plants in the South Coast.

The key point here is that no additional time-consuming work is necessary on the issue of NOx emission impacts. While the ARB staff believes the actual NOx emissions impacts are probably greater than those set forth in the TSD, the conclusions on NOx in the TSD are sufficient for the U.S. EPA to conclude that granting the waiver will assist California in its effort to reduce NOx emissions.

B. The NOx Emission Increases That the U.S. EPA Has Already Identified Necessarily Increase Ambient Concentrations of PM_{10} and $PM_{2.5}$ in California

Although the U.S. EPA never addressed the impact of the NOx emissions increase from the federal RFG oxygen mandate on PM concentrations in its TSD[11] or elsewhere, this issue is straightforward and can easily and quickly be resolved by the agency. Emissions of NOx have a substantial adverse impact on ambient concentrations of PM_{10} and $PM_{2.5}$ in California. In fact, achieving reductions in NOx emissions is the most

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[10] 65 FR 6698, 6717 (February 10, 2000).

[11] See TSD fn. 89 on p. 128: "We need not discuss the technical issues associated with an expected reduction in NOx [from a waiver] and any associated reduction in PM."

important control strategy in California's plans to attain and maintain the NAAQS for PM_{10}, and this will undoubtedly be the case with respect to the $PM_{2.5}$ NAAQS as well.

The main sources of NOx emissions are anthropogenic. NOx emissions are produced almost exclusively by combustion processes. During combustion, oxygen reacts with nitrogen to form nitric oxide (NO), nitrogen dioxide (NO_2), and relatively small amounts of other compounds of oxygen and nitrogen. When emitted to the atmosphere, these nitrogen by-products – which are collectively called NOx – are oxidized to form nitric acid. The nitric acid then reacts with gaseous ammonia to form ammonium nitrate. Since gaseous ammonia is generally in abundance in the California areas in question, the formation of ammonium nitrate from the nitric acid-gaseous ammonium reaction mechanism is dependent on the level of NOx emissions. Although VOC can play a role in the oxidation of NOx to nitric acid, ammonium nitrate is primarily responsive to reductions in NOx emissions, with minimal response to changes in VOC emissions.

Secondary ammonium nitrate comprises a large fraction of PM_{10} and even a larger fraction of $PM_{2.5}$ mass in California. The South Coast and San Joaquin Valley have the highest concentrations of ammonium nitrate. Roughly 20 to 30 percent of the annual average PM_{10} mass and 30 to 40 percent of the annual average $PM_{2.5}$ mass is ammonium nitrate in these areas. Basin-high annual average PM_{10} ammonium nitrate concentrations ranged from 11 $\mu g/m^3$ in the San Joaquin Valley to 27 $\mu g/m^3$ in the South Coast. The ammonium nitrate fraction is even larger on the peak PM days and was found to contribute up to 57 percent of PM_{10} mass and 84 percent of $PM_{2.5}$ mass. Peak 24-hour average PM_{10} ammonium nitrate levels in the South Coast Air Basin and the San Joaquin Valley Air Basin reached over 100 $\mu g/m^3$. With respect to $PM_{2.5}$, ammonium nitrate concentrations alone can exceed the federal $PM_{2.5}$ standards. A fuller discussion can be found in Attachment 1.

As discussed in more detail below, the PM_{10} nonattainment plans recently prepared for the South Coast and San Joaquin Valley Air Basins demonstrate that NOx emissions control is the most effective way to achieve attainment, along with reductions in primary PM_{10} components. It is clear that there are no significant technical issues regarding the relationship of NOx emissions to PM_{10} and $PM_{2.5}$ concentrations in California's federal RFG areas, and the U.S. EPA should be able to make the necessary determinations regarding that relationship without delay.

C. The Net Effect of the Federal RFG Oxygen Mandate on Emissions of All Pollutants In California Is To Increase Ambient PM_{10} and $PM_{2.5}$

While U.S. EPA concluded in its prior evaluation of the California waiver request that the federal RFG oxygen mandate increases NOx emissions in California, the agency also concluded that the mandate reduces emissions of CO and that its impact on VOC emissions was uncertain. This Section addresses the potential impact that changes in CO and VOC emissions caused by the oxygen mandate could have on ambient PM_{10} and $PM_{2.5}$, and the cumulative impact on particulate from changes in emissions of NOx, VOC and CO.

1. *The Reduction in CO Emissions Resulting From the Federal RFG Oxygen Mandate Does Not Affect Ambient PM_{10} and $PM_{2.5}$ in California*

The ARB has consistently acknowledged that the 2.0 wt.% minimum oxygen requirement in the federal RFG program reduces CO emissions from the existing fleet of vehicles on the road today. That is why the California Phase 2 and Phase 3 RFG standards impose a minimum oxygen requirement from November through February – when ambient CO concentrations are the highest – in the counties of Los Angeles, Orange, Riverside, San Bernardino, and Ventura (§§ 2260(a)(32.5) and 2262.5(a), title 13, California Code of Regulation (CCR)). These counties include the only remaining federal CO nonattainment area in the State.[12] In fact, California also imposes a minimum oxygen requirement from November through February in Imperial County as well. (§ 2262.5(a), title 13, CCR). This is because while Imperial County is designated as "unclassified" with respect to attainment of the NAAQS for CO, the ARB has designated it as being in nonattainment of the State ambient air quality standard for CO.[13]

While CO emissions do play a small role in ozone formation due to CO's limited reactivity, they do not appreciably affect ambient PM_{10} or $PM_{2.5}$ concentrations[14]. The simplest carbon containing molecule in the atmosphere, CO participates in the conversion of free radicals (hydroxyl radical to hydroperoxyl radical) that enhance the oxidation of NOx to nitric acid. However, there are several other paths to the same radical conversion and the role of CO in the oxidation of NOx to nitric acid is minor in the polluted atmosphere. CO does not play a direct role in the oxidation of VOCs into secondary organic aerosols[15].

The ARB staff is not aware of any guidance ever issued by the U.S. EPA indicating that CO emissions contribute to PM. To staff's knowledge, no PM_{10} attainment plan has ever included CO controls as a PM reduction strategy. Certainly the PM_{10} attainment plans recently prepared for the South Coast and San Joaquin Valley air basins do not attribute PM_{10} reductions to the CO reductions that continue to occur in those areas due to motor vehicle fleet turnover.

In light of these considerations, there would be no justification for delaying a waiver in order to analyze the potential impact of the CO emission increases that would result from a waiver on attainment and maintenance of the PM_{10} or $PM_{2.5}$ standards in California.

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[12] 63 FR 15305-15312 (March 31, 1998).

[13] A waiver of the federal RFG oxygen mandate would in no way hinder attainment of the NAAQS for CO because the CaRFG regulations will continue to require the use of oxygen in California's one CO nonattainment area during the season when exceedances of the CO NAAQS have occurred.

[14] Seinfeld, "Atmospheric Chemistry and Physics of Air Pollution", 1998

[15] "Particulate Matter for Policy Makers. A NARSTO Assessment", February 2003.

2. *Even Under the U.S. EPA's Worst-Case Projections of Potential VOC Increases In Certain Waiver Scenarios, the Net Effect of the Federal RFG Oxygen Mandate Is Clearly to Increase Concentrations of PM_{10} or $PM_{2.5}$ in California*

As discussed in Section V below, it is very unlikely given current information that a waiver of the federal RFG oxygen mandate will result in any increase in VOC emissions. However, even using U.S. EPA's worst-case projections in the TSD, it is clear that the net effect of the federal RFG oxygen mandate on both NOx and VOC emissions is to increase PM_{10} and $PM_{2.5}$ concentrations in California.

While VOC emissions have some effect on ambient PM_{10} or $PM_{2.5}$, on a pound-for-pound basis the contribution is much smaller than the contribution from NOx emissions. Table 31 of the TSD identified the VOC impacts from a waiver at various commingling-related Reid vapor pressure (RVP) boosts for the 12 specified scenarios. The absolute worst case shown in Table 31 for VOC increases resulting from a waiver is a Scenario 1 VOC increase of 9.23 tpd when there is a 0.2 psi boost in RVP due to commingling. Scenario 1 also shows a NOx emissions reduction of 6.60 tpd. Even in these worst-case circumstances, the combined impacts of the changes in NOx and VOC emissions due to a waiver have the demonstrable net effect of an overall reduction in PM concentrations.

The attainment demonstration procedures contained in the San Joaquin Valley and South Coast PM_{10} attainment plans provide a sophisticated means of comparing the potential impact of changes in NOx and VOC emissions on the PM_{10} concentrations in those two areas. The ARB staff has estimated the impact of a waiver on the peak annual average PM_{10} concentration in the South Coast Air Basin by applying a simple linear rollback approach with the Urban Airshed Model Long Term (UAM-LT) model results that were used in the attainment demonstration in the South Coast PM_{10} plan.[16] The incremental impacts of changes in NOx and VOC emissions on PM_{10} due to oxygenated gasoline were estimated by changing the projected NOx and VOC emissions in the rollback analysis by 10 tons per day. The results for the South Coast show that changing NOx emissions by 10 tons per day would change the peak annual PM_{10} concentration by 0.12 $\mu g/m^3$, while changing VOC emissions by the same amount would only result in a 0.011 $\mu g/m^3$ change in PM_{10} – over an order of magnitude less. Thus under U.S. EPA's <u>worst-case</u> Scenario 1, the 6.60 tpd reduction in NOx emissions from a waiver would result in a reduction in peak annual PM_{10} concentrations of 0.08 $\mu g/m^3$, while the VOC emissions increase of 9.23 tpd would increase annual PM_{10} concentrations by 0.01 $\mu g/m^3$, resulting in a net reduction in peak annual PM_{10} concentrations of 0.07 $\mu g/m^3$.

The ARB staff has also estimated the impact on the peak 24-hour PM_{10} value in the San Joaquin Valley following the procedure outlined in the San Joaquin Valley plan, which used both Chemical Mass Balance (CMB) modeling with grid-based

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[16] For the South Coast Air Basin, the ARB staff evaluated impacts on attainment of the annual PM_{10} standard because the annual standard is the most difficult to attain there. The highest annual design value of 56.8 $\mu g/m^3$ at Riverside-Rubidoux was used in the analysis.

photochemical aerosol chemistry modeling analysis (UAM-Aero), combined with proportional rollback to demonstrate attainment.[17] The results show that while changing NOx emissions by 10 tpd a day would change the peak 24-hour PM_{10} concentration by 1.5 µg/m^3, changing VOC emissions by the same amount would only result in a 0.14 µg/m^3 change in the peak 24-hour PM_{10} concentration. Again, there is an order of magnitude difference between the impact of changes in NOx emissions and changes in VOC emissions.

The relative importance of NOx and VOC controls as PM reduction strategies is also illustrated by the role they play in the two recently-prepared PM_{10} attainment plans. In the San Joaquin Valley Air Basin, approximately 19 µg/m^3 in PM_{10} reductions came from reductions in ammonium nitrate and 2 µg/m^3 came from reductions in secondary organic carbon. In the South Coast, approximately 13 µg/m^3 in PM_{10} reductions came from reductions in ammonium nitrate and 0.2 µg/m^3 came from reductions in secondary organic carbon.

Emission reductions that lower PM_{10} concentrations will also lower $PM_{2.5}$ concentrations. Because almost all of the ammonium nitrate and secondary organic carbon can be found in the $PM_{2.5}$ size fraction, the results presented for PM_{10} are also applicable for $PM_{2.5}$.

Attachment 1 provides the details on the various estimates in this Section regarding the impacts of NOx and VOC emissions.

IV. THE SUBSTANTIAL NET INCREASES IN PM THAT RESULT FROM THE FEDERAL RFG OXYGEN MANDATE, COUPLED WITH THE CURRENT PM NONATTAINMENT STATUS OF MOST FEDERAL RFG AREAS IN CALIFORNIA, NECESSARILY MEAN THAT THE FEDERAL RFG OXYGEN MANDATE IS PREVENTING OR INTERFERING WITH ATTAINMENT OF THE NAAQS FOR PM_{10} or $PM_{2.5}$ IN THE STATE

As discussed above, the substantial NOx increases that result from the federal RFG oxygen mandate contribute to PM_{10} or $PM_{2.5}$ concentrations in the federal RFG areas in California. It necessarily follows that these NOx increases prevent or interfere with attainment of the PM_{10} or $PM_{2.5}$ NAAQS in those areas where the ambient standards are not presently attained.

This conclusion is not negated by the fact that the PM_{10} State Implementation Plans for the San Joaquin Valley and South Coast air basins ultimately demonstrate attainment with the PM_{10} NAAQS, for three reasons. First, both air basins are presently in nonattainment of the NAAQS for PM_{10}, and the federal RFG oxygen mandate is resulting in real and immediate increases in PM. They would be closer to attaining the NAAQS for PM_{10} right now if it was not for the additional NOx emissions caused by the

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[17] The 24-hour PM_{10} standard is the most difficult to attain in the San Joaquin Valley. The ARB staff therefore evaluated the potential impacts on 24-hour concentrations using the highest 24-hour design value at Bakersfield-Golden of 205 µg/m^3.

federal RFG oxygen mandate. Second, the attainment plans for the PM_{10} NAAQS in the South Coast and San Joaquin Valley air basins are based on an on-road vehicle emissions inventory model (EMFAC model) that takes into account CaRFG3 program. Thus denial of the waiver will prevent the two air basins from realizing the full emission benefits of the program. Finally, attainment with the NAAQS for $PM_{2.5}$ has not yet been demonstrated and significant additional unidentified control measures are needed for attainment. Thus the federal oxygen mandate clearly prevents or interferes with attainment of the $PM_{2.5}$ NAAQS.

V. IN LIGHT OF NEW EVIDENCE THE PREVIOUS U.S. EPA FINDING THAT A WAIVER OF THE RFG OXYGEN MANDATE MIGHT ADVERSELY AFFECT VOC EMISSIONS AND THEREFORE INCREASE OZONE LEVELS CAN NO LONGER BE JUSTIFIED

Since the U.S. EPA's original denial of the waiver, the available data on the impact of a waiver on VOC emissions has been supplemented in two important areas: (a) the VOC permeation emission increases from nonroad equipment and gasoline cans that result from an increased use of ethanol in gasoline, and (b) the degree to which a waiver will result in increased emissions of VOC due to "commingling." When the impact of those changes in emissions are taken into account, it is abundantly clear that a waiver will not increase VOC emissions and therefore would not hinder attainment of the ambient ozone standard in California.

A. Increases in Evaporative VOC Emissions Due to Permeation When Gasoline Containing Ethanol Is Used in Nonroad Equipment and Portable Gasoline Containers

In its 2001 waiver analysis, the U.S. EPA used the ARB's estimates regarding increases in permeation emissions from motor vehicles ethanol-blended gasoline. New test data now allow the quantification of the significant permeation emission increases from nonroad equipment and gasoline cans that result from application of the federal RFG oxygen mandate in California.

It is well known that the presence of ethanol in gasoline can increase emissions through a process known as permeation. Permeation emissions occur when fuel compounds found in gasoline permeate through the non-metallic fuel system components, such as hoses and gaskets. Increases in permeation emissions increase evaporative VOC emissions. Systems that experience permeation can include the fuel systems of gasoline-powered motor vehicles, nonroad engines such as those used in lawn mowers and blowers, and watercraft. Permeation emissions are also associated with portable gasoline containers.

The materials submitted by the ARB to the U.S. EPA in February 2000 to support the waiver included estimates of the extent to which a waiver would decrease evaporative VOC emissions due to permeation losses from the use of ethanol-blended gasoline in on-road vehicles. These estimates of permeation losses were derived from the available fuel permeation data from two Society of Automotive Engineering (SAE) Technical Papers, 920163 and 970307. The ARB staff concluded that changing federal RFG gasoline in California from 2.0 wt.% oxygen from ethanol to nonoxygenated gasoline would reduce VOC evaporative emissions due to permeation from on-road vehicles by about 13 tpd.[18] Since about 60 percent of all federal RFG in California is sold in the SCAB, the reduction in VOC evaporative emissions from permeation in the SCAB would be about 7.8 tpd, assuming 100 percent penetration of nonoxygenated fuels.

In its analysis of California's waiver request, the U.S. EPA recognized the potential for increased permeation emissions when ethanol is added to gasoline. Acknowledging that "CARB's predicted increases are based on conservative estimates,"[19] the U.S. EPA incorporated the ARB's permeation estimates into the agency's overall analysis of the impacts of a waiver. The actual impact in any given waiver scenario would depend on the market share of nonoxygenated gasoline and the percentage of ethanol in gasoline. Table 27 of the U.S. EPA's TSD shows the decreases in permeation emissions under the 12 scenarios, which range from 3.7 to 8.5 tpd in the SCAB.[20] However, these estimates do not account for permeation from off-road sources. Since then two studies have been conducted to quantify permeation emissions from these sources.

The first study estimated the impact of ethanol gasoline on evaporative emissions from small engines such as lawnmowers, blowers, chainsaws, and other lawn and garden equipment (see Attachment 2)[21]. Based on the test results of five lawn mowers using commercial California gasoline containing 6 percent ethanol, evaporative emissions increased by up to 49 percent. Applying this factor to the approximately 20 tpd evaporative emissions from non-marine offroad engines statewide[22] results in about a 10 tpd evaporative emissions increase, or about a 4 tpd evaporative emissions increase in the SCAB.

The second study estimated the permeation emissions of storing ethanol gasoline in portable fuel containers (see Attachment 3)[23]. The study found that the additional evaporative emissions from portable fuel containers containing 10 vol.% ethanol in gasoline are about 8 tpd statewide. The test results also indicated that the presence of about 5.25 vol.% ethanol in gasoline increases permeation emissions from untreated containers by more than 60 percent, or about 5 tpd. This translates into an evaporative emissions increase of about 2 tpd for the SCAB.

Table 1 reflects the permeation emissions identified by U.S. EPA in Table 27 of the TSD, with additional columns representing permeation emissions from non-marine offroad engines and gasoline containers. These emissions values are derived from the

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[18] February 7, 2000 ARB submittal to U.S. EPA, Attachment at p. 19.
[19] TSD at 102
[20] TSD at 101
[21] California Air Resources Board, "Evaporative Emissions from Offroad Equipment," 2001.
[22] February 7, 2000 ARB submittal to U.S. EPA, Attachment (Table 4).
[23] California Air Resources Board, "Test Protocol and Results for the Determination of Permeation Rates from High Density Polyethylene Containers and Barrier Surface Treatment Feasibility Study," 2001.

two studies described above which showed that adding 5-6 percent ethanol to all gasoline would increase the SCAB permeation emissions from the additional sources by about 6.5 tpd.

Table 1 (Expansion of Table 27 in the TSD)
VOC Emission Reductions Due to Reductions of Permeation Losses with Waiver

					EPA's Permeation Emissions On-road Vehicles (VOC, tpd)			Additional Permeation Emissions Offroad Engines (VOC, tpd)		
No Wvr oxy wt.%	Wvr oxy wt.%	Nat'l MTBE Use	Unocal Patent	Non-oxy Penetration Pct.	Oxy no wvr to non oxy	Oxy no wvr to oxy wvr	Total	Oxy no wvr to non oxy	Oxy no wvr to oxy wvr	Total
2.0	2.0	Reduced	Applies	65	-5.1	0.0	-5.1	-2.6	0.0	-2.6
2.7	2.7	Reduced	Applies	60	-6.3	0.0	-6.3	-3.2	0.0	-3.2
2.7	2.0	Reduced	Applies	65	-6.8	-0.9	-7.8	-3.5	-0.5	-3.9
2.0	2.0	Continues	Applies	50	-3.9	0.0	-3.9	-2.0	0.0	-2.0
2.7	2.7	Continues	Applies	40	-4.2	0.0	-4.2	-2.1	0.0	-2.1
2.7	2.0	Continues	Applies	50	-5.3	-1.4	-6.6	-2.7	-0.7	-3.4
2.0	2.0	Reduced	Avoided	74	-5.8	0.0	-5.8	-2.9	0.0	-2.9
2.7	2.7	Reduced	Avoided	54	-5.7	0.0	-5.7	-2.9	0.0	-2.9
2.7	2.0	Reduced	Avoided	74	-7.8	-0.7	-8.5	-3.9	-0.4	-4.3
2.0	2.0	Continues	Avoided	50	-3.9	0.0	-3.9	-2.0	0.0	-2.0
2.7	2.7	Continues	Avoided	35	-3.7	0.0	-3.7	-1.9	0.0	-1.9
2.7	2.0	Continues	Avoided	50	-5.3	-1.4	-6.6	-2.7	-0.7	-3.4

It is noteworthy that the estimates in Table 1 do not include emissions from potentially significant sources, such as marine pleasure craft and fuel dispensing equipment. Thus the values in Table 1 are likely to still underestimate the full permeation impacts associated with the use of ethanol fuels.

In addition to the studies described above, the Coordinating Research Council (CRC) is currently conducting a permeation test program using fuel system components extracted from 10 California vehicles selected based on their contribution to the California on-road fleet. This study is designed to estimate the impact of ethanol in gasoline on permeation emissions from California motor vehicles based on the entire fuel system rather than individual components. The vehicle sample was chosen based on its representation of the model year distribution of motor vehicles within the California fleet. The final results of this study are not yet available but we expect they will be consistent with those of earlier permeation studies demonstrating that permeation emissions are significant and that the presence of ethanol in gasoline tends to increase emissions over what would be expected from a comparable fuels without ethanol.

B. The ARB's Assessment of the Real-World Impacts of Commingling California Phase 3 Reformulated Gasoline

1. *Overview of the Commingling Effect*

Adding ethanol to nonoxygenated gasoline results in a non-linear increase in RVP and the gasoline's propensity to evaporate. Essentially all of the RVP boost occurs by the time a gasoline mixture contains about 5 vol.% ethanol. At this blending level, the ethanol will have raised the RVP of the gasoline by about 1 psi. Because of this phenomenon, mixing ethanol-blended gasoline with nonoxygenated gasoline will increase the RVP of the resulting blend relative to the RVPs of the two gasoline components. For example, adding 10 gallons of gasoline that contains 6 vol.% ethanol and has an RVP of 7.0 psi to a vehicle fuel tank containing 10 gallons of nonoxygenated gasoline that has an RVP of 7.0 psi will result in a gasoline mixture having an RVP of about 7.5 psi. This boost in RVP is called the "commingling effect." Both the federal RFG and the CaRFG regulations generally prohibit suppliers of gasoline from mixing ethanol-blended gasoline with non-ethanol gasoline during the RVP season because of the commingling effect, but there are no restrictions on consumers commingling gasoline in a vehicle's fuel tank.

Without a waiver, all of the gasoline sold in the federal RFG areas in the state will contain at least 2 wt.% oxygen from ethanol – about 5.7 volume percent (vol.%) ethanol – once California's MTBE ban takes full effect in 2004. Under this circumstance, there would be no commingling effect for vehicles fueled only within the federal RFG areas. With a waiver, there will some emissions resulting from commingling because it is expected that some suppliers will offer gasoline that contains ethanol and others would not.

The effect of commingling on the average RVP in a given area depends on a number of variables in two basic areas – the gasoline market and consumer refueling habits. The two key gasoline market variables are the percentage of ethanol-blended gasoline in the marketplace, and the volume of ethanol in the ethanol blends. The key consumer habits are brand loyalty, fuel tank levels prior to refueling, fillup vs. non-fillup preference, and the quantity of gasoline purchased. Some of these variables can have a significant impact on the magnitude of the commingling effect on emissions. For instance, since gasoline stations will normally not switch from ethanol gasoline to nonoxygenated gasoline during the RVP season, there would generally be no commingling effect at all if all motorists maintained 100 percent brand loyalty. Similarly, the commingling effect would be minimal if motorists refueled only when their fuel tanks were almost empty.

In order to evaluate the size of the commingling effect in a particular area, one can use a computer model that will simulate the effect of consumer fuel purchasing decisions under a variety of assumed conditions. The inputs for the model consist of data and assumptions regarding gasoline marketing and data and assumptions regarding consumer refueling habits. The ultimate utility of a modeling exercise will depend on the validity of the data and assumptions and the soundness of the simulation model itself.

2. *The U.S. EPA's Commingling Analysis Used to Deny the Oxygen Waiver*

To support California's waiver request, the ARB submitted an estimate of the impact of the commingling effect based on a simulation model and a number of assumptions about the gasoline market and consumer refueling behavior. No actual refueling data were available for motorists in California's federal RFG areas or the rest of the state, so ARB staff based its assumptions on expected consumer habits. This analysis showed that there would be an average RVP increase of about 0.10 psi for all gasoline if fuel tanks were typically a quarter tank full at refueling, and an increase of about 0.13 psi if fuel tanks were typically half-full.

However, the U.S. EPA decided not to rely on the ARB staff's commingling assumptions, because "the conditions that would be applicable to the Federal RFG areas in California if a waiver were granted are largely unknown."[24] The agency instead turned to a commingling analysis that used a simulation model that had been published by U.S. EPA staff members Caffrey and Machiele in 1993[25] (the 1993 U.S. EPA Commingling Analysis). This analysis referred to two data sets pertaining to brand loyalty, which has the largest overall impact on the overall commingling effect. As discussed in Section V.B.4. below, the study authors made major adjustments to these data, which had been generated in 1981 and 1992. In its waiver consideration the U.S. EPA also cited the Sierra Research commingling analysis[26] that basically used the same U.S. EPA simulation model but applied the model specifically to California.

In its denial to California waiver request, the U.S. EPA stated "We believe, <u>in the absence of better information</u> 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 pi rather than 0.1 pi." (TSD p. 110; emphasis added.) The agency further indicated that a "plausible case" could be made for average commingling effects as high as 0.3 pi.

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[24] TSD, p. 106.

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

[26] Sierra Research, "Potential Evaporative Emission Impacts Associated with the Introduction of Ethanol-Gasoline Blends in California," prepared for American Methanol Institute, Report # SR00-01-01, January 11, 2000.

3. *The ARB's Commingling Study*

The ARB staff has now completed a significantly new commingling study (the ARB Commingling Study) that provides recent data on California consumers fueling habits from observations of almost 400 fuelings. Using a probabilistic simulation model to process refueling information based on the newly collected data and ethanol market share assumptions, the ARB is now able to estimate that the likely commingling effect from a waiver is an average RVP increase of approximately 0.06 psi. The effect of this new information on U.S. EPA's earlier waiver analysis is shown in Section V.C. below.

The ARB's simulation modeling is reinforced by elements of the commingling study in which the RVP impacts from mixing different types of fuels were identified by sampling and testing the fuel in vehicle fuel tanks before and after fueling, as well as the fuel being dispensed. This analysis indicated a statewide average commingling impact of approximately 0.07 psi.

Both the simulation modeling and field sampling efforts are described in detail in Attachment 4 – the August 2003 Draft Report on the Assessment of the Real-World Impacts of Commingling California Phase 3 Reformulated Gasoline (the ARB Commingling Report). The overall study focused primarily on a comparison of the emission impacts from the CaRFG3 and CaRFG2 programs, to determine whether the emission benefits from the State's gasoline programs are being maintained. However, the staff also analyzed the data to address U.S. EPA's concerns about the commingling effect resulting from a waiver.

In the ARB Commingling Study, ARB staff observed motor vehicle fuelings at a total of 19 gasoline outlets in three areas of the State – the Los Angeles area, the San Francisco Bay Area, and Lake Tahoe. The latter area was included to increase the number of expected commingling events during field sampling, since the voluntary early phase-out of MTBE at Lake Tahoe meant that ethanol-blended fuels were much more prevalent there. The study included observations of 175 vehicle fuelings at Lake Tahoe, 121 in the Bay Area, and 100 in Los Angeles. Samples from the fuel tanks of 254 of these vehicles were also taken.

Brand loyalty was measured by asking each consumer if a different brand of gasoline was used for the last fueling of the vehicle. For purposes of the model, non-loyal consumers were assumed to be those who answered "yes" or "do not know." It was assumed that fueling by consumers characterized as "brand-loyal" resulted in no or negligible commingling occurring in their vehicle tanks. The other consumer refueling activities were accordingly included in the modeling analysis only for consumers who were not characterized as brand-loyal. Since there are major constraints on gasoline stations switching between non-ethanol and ethanol-blended gasoline during the summertime RVP season, a brand-loyal consumer can be expected receive the same type of fuel for every fueling.

The decision to characterize loyal consumers as those who purchased the same fuel brand in the last two fuelings was a consensus of the ARB/Industry working group that oversaw the study. The group believed that asking consumers regarding their brand loyalty from a history of previous fuelings beyond the last fueling might produce an unreliable answer. The loyalty levels showed in the ARB survey is consistent with the NPD survey data for California, taking into account that a brand switch would not necessarily produce commingling. In addition, the group hypothesized that most consumers would fuel at low tank levels, so only the remaining fuel from the last fueling, together with the dispensed fuel, would have a significant effect on the final fuel's RVP. This hypothesis was also consistent with the survey findings, where about 80 percent of consumers fueled at ¼ tank full gasoline or less, with more than 40 percent registering nearly an empty tank. Approximately half of consumers opted for a fillip. [See Attachment 4, pp. 21-23].

Table 1 shows the consumer fueling habits observed during the 2001 ARB field study.

Table 1. The 2001 ARB Data for Simulation Model Input*

Variables (All but Brand Loyalty Calculated for Non-Loyal Consumers Only)	**Lake Tahoe**	**S.F. Bay Area**	**Los Angeles**
Consumer Not Brand Loyal (%) [Includes "don't know" group]	69	42	38
Average Initial Fuel Tank Levels (as fraction of usable tank capacity)	0.23	0.2	0.18
Fillup (%)	52	58	24
Average Fuel Amount Purchased for Non-Fillup (as fraction of usable tank capacity)	0.35	0.32	0.37

*The model assumed 5% tank heel, derived from the SwRI's report [see footnote 26]

In selecting the anticipated market conditions to be used in the simulation modeling, ARB staff used the best available data, including recent reports and stakeholder consultations. Given the uncertainty, the staff concluded it was necessary to assume various scenarios that are expected to bracket a wide range of commingling impacts. As for ethanol market share, the staff assumed that the future California ethanol market share would vary from 25 to 65 percent. Modeling was accordingly conducted for nine different ethanol market share splits, reflecting the entire range from 25 to 65 percent, in five percent increments. This is consistent with the different scenarios developed by MathPro for U.S. EPA. The staff further assumed that the ethanol market share would be the same for all grades. After consulting with gasoline producers the staff assumed that the ethanol blends would be produced with either 6 vol.% or 7.7 vol.% ethanol; very little gasoline containing 10 vol.% ethanol has been marketed in California.

The data were analyzed by using the "UCD simulation model," developed by Dr. David Rocke at the University of California Davis. Inputting assumed future ethanol market conditions as well as consumer fueling behavior from the field study, ARB staff simulated a total of 162 fueling scenarios. Pertinent model results are provided on 45-49 of the ARB Commingling Report. As expected, the anticipated commingling effect increases with ethanol market penetration, and peaks at around 45 percent to 50 percent market share. For the base case scenario using a mid-range ethanol purchase propensity distribution, the model estimates average statewide commingling impacts of 0.055-0.069 psi RVP for 6 vol.% ethanol blends and 0.062-0.077 psi RVP for 7.7 vol.% ethanol blends.

Most if not all of the ethanol blends in California are expected to contain a maximum of 6 vol.% ethanol. Both the federal and California RFG requirements restrict the mixing of California reformulated blendstock for oxygen blending (RBOB or CARBOB) designed for one ethanol level with RBOB or CARBOB designed for another ethanol level. Coupled with the physical constraints on common carrier pipelines in the state, this means as a practical matter that pipeline-distributed gasoline will generally have the same amount of ethanol added. To date, the ethanol content has been around 5.7 vol.% – the minimum amount needed to achieve an oxygen content of 2.0 wt.%. Since this practice is expected to continue, it is appropriate to estimate the potential commingling effect based on ethanol levels of 6 vol.% in any waiver analysis.

4. *Reasons for the Differences in Results Between the U.S. EPA's Commingling Analysis and the ARB Commingling Study*

The differences in the results of the ARB commingling study and the U.S. EPA commingling analysis are due to a number of factors.

- **Modeling Assumptions**

The ARB analysis assumed negligible commingling impacts from brand loyal consumers. These brand loyal consumers got the same type of fuel, ethanol or non-oxygenate gasoline, since CaRFG3 regulations prohibit mixing two different types of gasoline in underground fuel tanks at retail stations. In addition, brand switching may not necessarily result in an RVP increase if the two brands are of the same fuel type.

In contrast, the U.S. EPA analysis assumed almost all consumers were not brand loyal, hence virtually every fueling event was associated with commingling that contributed to an RVP increase.

- **Data**

The 2001 ARB field study data were specific to California gasoline consumers. The study found that consumer fueling habits varied by region. Consumers in the urban areas (the Bay Area and Los Angeles) tended to be more brand loyal and to fuel at lower initial fuel tank levels than their counterparts in the rural areas (Lake Tahoe).

Though not as pronounced, some differences were also observed among consumers in the urban areas. The ARB analysis took into account these regional differences, and these detailed survey data allowed regional commingling impacts to be estimated separately. These estimates were then used to infer the statewide potential commingling impacts.

In contrast, the U.S. EPA data were not based on the current California consumers fueling habits. Therefore, the U.S. EPA data are a less reliable basis to assess the potential commingling impacts in California. In fact, the U.S. EPA's consumer fueling data were gathered from surveys conducted on different groups of consumers at various times and purposes, so they did not represent coherent information on any particular consumers. Aware of these shortcomings, the U.S. EPA purposely modified the data to ensure they produce a very conservative commingling impact. A commingling analysis based on such data is bound to predict a greater effect than is likely to occur.

Consumer Loyalty

Brand loyalty assumptions are of paramount importance, and the U.S. EPA indicated in the TSD that, "The magnitude of the commingling effect is highly sensitive to brand loyalty."[27] The 1993 U.S. EPA Commingling Analysis refers to two sets of data regarding brand loyalty. The primary set of data discussed in the analysis had been submitted by ARCO to U.S. EPA in 1981, and consisted of the following:

Brand Loyalty – 1981 ARCO Data

Percentage of Time Consumer Purchases Favorite Brand of Gasoline	Percent of Respondents in The Particular Category
0 – 25%	2
26 – 50%	12
51 – 75%	23
76 – 100%	63

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[27] TSD, p. 112.

The other set of data was collected in 1992 by the NPD Group Inc. as part of its annual gasoline analysis prepared under contract with U.S. EPA. These data showed:

Brand Loyalty – 1992 NPD Group Data for Total U.S. Industry

Brand Grouping	Percentage
Use Many Different Brands	11.0%
Use 2 or 3 Brands	51.2%
Always Use One Brand	37.8%

The authors of the 1993 U.S. EPA Analysis concluded that the ARCO data "appeared to be unrealistic" because they "indicated a great propensity towards extremely high customer loyalty." [SAE paper, p. 2]. The authors smoothed the data by shifting loyal consumers towards non-loyal consumers, and claimed these modified data were supported by the NPD data. This claim was inaccurate since the modified data showed practically no loyal consumers. As shown in the following table, several curves were used to fit the ARCO data, but none of them resembled the NPD data.

Modified Brand Loyalty from the Original 1981 ARCO Data

U.S. EPA Curve Fitting on ARCO Brand Loyalty Data	Loyal Consumers*
Fitted "Curve 2"	1%
Fitted "Curve 3"	1%
Fitted "Curve 4"	0%

*Always use one brand

The primary justification used by the authors for these curve fittings was that the ARCO data did not specifically specify the distribution of consumers in the 75%-100% loyalty range, but showed a lump sum of 63 percent of surveyed consumers fell in this range. Although this was true, they could have utilized the NPD data to determine the proportion of loyal consumers that "always use one brand," since about 38 percent of the NPD consumers were in this category. As can be seen from the above table, the fitted curves dramatically distorted the proportion of loyal consumers, contrary to what the NPD data showed.

Also, the 1993 U.S. EPA Analysis failed to take into account the fact that brand loyalty data served as a surrogate to fuel type loyalty data. Ideally, the latter data should be used to model the commingling impact since brand switching may not result in an RVP boost if both brands sell the same fuel type. Although the authors recognize that "the loyalty curves the model uses are applicable only to a fuel brand and not a particular oxygenate," [SAE paper, p.2] they again failed to utilize the NPD data that could have been used to conservatively estimate the proportion of non-loyal consumers that would not contribute to commingling. For example, if ethanol blends and non-oxygenated gasoline are equally distributed among four brands of gasoline from which non-loyal consumers, who use two brands equally, would choose, at least a third of these consumers would not experience an RVP boost from mixing two different gasoline brands in their vehicle tanks. Applying this estimate to the NPD data above and assuming consumers were equally distributed between using two and three brands, at least 8.5 percent of consumers would not contribute to an increase in emissions due to commingling of ethanol and non-ethanol fuels. Using the above reasoning for "use three brands" consumers, at a minimum another 5 percent of consumers would also not contribute to an increase in emissions due to commingling.

In summary, the U.S. EPA analysis assumed that essentially no brand loyal consumers exist, and that every brand switching resulted in commingling and produced an RVP increase. Both of these assumptions are unrealistic. All else being equal, the erroneous approach used by U.S. EPA could at least double the RVP increase.

Consumer Fueling Patterns and Tank Heel

The U.S. EPA analysis used a General Motors (GM) survey of about 1,100 refueling events to describe consumer fueling patterns, but it was not clear when and where the survey was conducted. The GM data showed that more than half of consumers fueled at 0.1 full tank or less. Rather than relying on mean and standard deviation of the data to fit a curve as called for in a standard statistical approach, the U.S. EPA, as in the consumer loyalty case, used an approach designed to inflate the commingling impact that had no scientific basis. As a result, the modified data indicated that most consumers fuel at a higher tank levels, with only about 40 percent of consumers fueling a tank that is 0.1 full or less. Moreover, the U.S. EPA assumed a tank heel of 10 percent tank capacity. It was not clear what was the source of this assumption, which appears to be too high. A Southwest Research Institute (SwRI) report on fuel tank flush effectiveness of five vehicles found that, on average, tank heel is about 5 percent of tank capacity.[28] Higher tank heel and initial tank levels mean that more fuel is left in the fuel tank to readily commingle with the dispensed fuel.

Similarly, for the dispensed fuel, the U.S. EPA smoothed the GM data that resulted in less amount added to vehicle fuel tank during fueling. This was done by reducing the fraction of consumers who refill to a full tank from more than 40 percent in the original GM data to only about 20 percent. The reduction of fillup frequency decreased the dilution effect of the dispensed fuel on the remaining fuel in vehicle tank, and therefore increased the RVP boost from the commingling.

In summary, as was the case with consumer loyalty, the U.S. EPA study authors modified the data on consumer refueling patterns and assumed an unreasonable high

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[28] Southwest Research Institute, "A Vehicle Fuel Tank Flush Effectiveness Evaluation Program," prepared for Coordinating Research Council, Inc., SwRI Project 08-31088, August 20, 2001.

tank heel in a direction that increased the impact of commingling. Collectively, these two additional factors increased the commingling impacts by 20 to 30 percent.

- **Computer Model**

The ARB commingling study utilized a modeling method that can represent complex consumer fuel purchase decisions. Such an approach allows uncertainties in consumer decision-makings fully accounted for. The ARB study also included direct measurements of RVP increases in consumers' vehicle fuel tanks. The model produced commingling estimates that are consistent with the field measurements.

The computer model used in the U.S. EPA analysis employed an approach that did not allow random variations in fueling habits by consumers. For example, in simulating consumers' brand loyalty the model uses pre-determined values that were not randomly generated from any known statistical distribution. These values are biased toward non-loyal consumers. As a result, the model tended to overestimate the commingling impacts.

- **Corrected U.S. EPA Analysis**

If the U.S. EPA estimate of a likely 0.2 psi RVP increase from commingling is corrected due to reasons discussed above, the RVP increase would be less than 0.1 psi [i.e., 0.2 psi x 0.5 due to modified consumer loyalty x 0.75 due to modified consumer fueling patterns and tank heel]. This figure is more in line with the ARB estimate using the 2001 field survey in federal RFG areas in California as briefly described in the following section. Note: a critique by Dr. Gary Whitten also found that the U.S. EPA analysis overestimated the commingling effect. Dr. Whitten conclude that if the model used in the U.S. EPA analysis were adjusted to fix misrepresentations of the ARCO and GM data, the commingling effect is an RVP increase of about 0.07 psi.[29]

C. When the Additional Data on Permeation and Commingling Are Considered, It is Clear the Waiver Will Not Hinder Attainment and Maintenance of the Ozone NAAQS In California's Federal RFG Areas and There is Accordingly No Basis for Denial of the Waiver

In Table 31 of its TSD, U.S. EPA portrayed what it believed the range of possible exhaust and evaporative emissions impact of a waiver in the South Coast Air Basin under the 12 waiver scenarios that had been developed by MathPro. The table reflected the agency's various determinations and showed the VOC emissions impact of three RVP boost scenarios from commingling – no boost, an 0.1 psi boost, and an 0.2 psi boost. Adjustments to that table are needed to show the effect of the new information on permeation and commingling emissions. To illustrate what we believe an improved assessment would provide, ARB staff has prepared an Adjusted Table 31,

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[29] Whitten, G.Z., "Analysis of Commingling due to Ethanol Blends," System Applications International, May 1999.

shown below, that reflects the new data being provided. The Adjusted Table 31 reflects the following modifications to the original table:

- An "0.06 psi RVP Boost" column has been substituted for the TSD's three columns of "VOC no boost," "VOC 0.1 psi boost," and "VOC 0.2 boost." The 0.06 RVP boost represents an average commingling impacts from 5.7 vol.% ethanol blend for various ethanol market shares in SCAB. The "0.06 RVP Boost" column includes all of the non-commingling VOC emissions shown in the original Table 31 "VOC no boost" column (including permeation emissions from on-road vehicles). Added to these VOC emissions are the commingling emissions from an 0.06 psi boost in RVP, derived by applying linear extrapolation to the sum of the on-road and nonroad "0.1 psi Commingling" columns in Table 32 of the TSD.

- A column for non-road permeation emissions has been added to reflect the new permeation data described above. Note that this excludes the impact of permeation emissions from pleasure craft.

- A new column has been added on the far right to show the total change of combined NOx and VOC.

Table 31: Waiver Impacts on Ozone (Revised)

				Waiver Case Oxygen Market Share and Oxy Levels			Emission Inventory Changes (tpd) (on-road, off-road and all Exhaust and evap VOC, such as permeation and commingling)				
No Wvr Oxy Level	Wvr Oxy Level	Nat'l MTBE Use	Unocal Patent	% Oxy Fuel	% Non-Oxy Fuel	Yr-round Oxy Ave	NOx	VOC 0.06 psi Boost	Off-road Permeation*	Total VOC	Total NOx+VOC
2.0	2.0	Reduced	Applies	35	65	1.0	-6.60	-0.08	-2.4	-2.48	-9.08
2.7	2.7	Reduced	Applies	40	60	1.5	-7.53	-11.59	-2.9	-14.49	-22.02
2.7	2.0	Reduced	Applies	35	65	1.0	-9.61	-12.58	-3.7	-16.28	-25.89
2.0	2.0	Continues	Applies	50	50	1.3	-5.08	-0.16	-1.8	-1.96	-7.04
2.7	2.7	Continues	Applies	60	40	1.9	-4.68	-5.99	-2.0	-7.99	-12.67
2.7	2.0	Continues	Applies	50	50	1.3	-8.21	-12.70	-3.1	-15.80	-24.01
2.0	2.0	Reduced	Avoided	26	74	0.9	-7.20	-5.23	-2.7	-7.93	-15.13
2.7	2.7	Reduced	Avoided	46	54	1.6	-7.08	-8.42	-2.7	-11.12	-18.20
2.7	2.0	Reduced	Avoided	26	74	0.9	-10.89	-11.88	-4.0	-15.88	-26.77
2.0	2.0	Continues	Avoided	50	50	1.3	-4.84	-4.35	-1.8	-6.15	-10.99
2.7	2.7	Continues	Avoided	65	35	2.0	-4.78	-5.62	-1.7	-7.32	-12.10
2.7	2.0	Continues	Avoided	50	50	1.3	-8.73	-11.06	-3.1	-14.16	-22.89

* Excluding marine pleasure craft and gasoline dispensing equipment

It can be seen from Adjusted Table 31 that NOx emissions decrease in all 12 scenarios, with the decrease ranging from approximately 5 tpd to 11 tpd. These impacts are unchanged from U.S. EPA's original analysis. VOC emissions also decrease in all scenarios. The combined emissions of NOx and VOC, as shown in the last column, range from about 7 to 27 tpd reductions.

It is important to understand the strengths and limitations of the scenarios used in the U.S EPA analysis. The fuel properties in each individual scenario were developed by MathPro Inc. and are based upon an extensive list of assumptions that may not accurately represent future operational characteristics of the California refining industry. For example, based upon a survey of California's refining industry, ARB staff found that overall sulfur concentrations for CaRFG3 would average about 10 ppm or less. Of the 24 different sets of CaRFG3 fuel properties generated for the U.S. EPA by MathPro Inc. over 70 percent are predicted to have sulfur concentrations of 10 ppm or higher. Also, MathPro Inc. used an input price of $25/Bbl for Saudi Light crude oil. In 2003, crude prices have consistently average about $30/Bbl. These departures from the original assumptions suggest that individual sets of fuel properties should not be relied upon to accurately assess the expected changes in emissions associated with a waiver, but should be used to determine the direction and magnitude of the changes.

Background Information on Federal RFG Oxygenate Waiver Impacts on Particulate Matter

Prepared by

Planning & Technical Support Division
California Air Resources Board

(Revised September 19, 2003)

Contribution of Ammonium Nitrate to PM10 and PM2.5 in California

PM10 and PM2.5 concentrations vary widely throughout California. In general, both the highest 24-hour and annual average concentrations are found at sites in the South Coast Air Basin and San Joaquin Valley Air Basin, which are both currently designated as serious nonattainment for the federal PM10 standards. These two air basins, along with San Diego, are expected to be designated as nonattainment for the federal PM2.5 standard as well in 2004. However, relatively high 24-hour measurements are also found in the Sacramento Valley Air Basin, San Francisco Bay Area Air Basin, and certain parts of the Mountain Counties Air Basin. The highest PM10 and PM2.5 concentrations occur between mid-November and mid-February when several source contributions are superimposed on each other. This seasonal pattern is typical for most of California but is most pronounced in the San Joaquin Valley Air Basin. The exception is the South Coast Air Basin, where high values occur throughout the year.

Elevated particulate matter (PM) concentrations result from a combination of emissions, transport, transformation, and accumulation of pollutants. Atmospheric PM is a complex mixture of a variety of primary and secondary particles differing in size and chemical composition. Primary particles are directly emitted by sources while secondary particles form from directly emitted gases by transformation in the atmosphere. The relative importance of primary and secondary particles depends on many factors, including precursor emissions, atmospheric chemistry, and meteorology. Secondary ammonium nitrate comprises a large fraction of PM10 and even a larger fraction of PM2.5 mass in California. The two serious federal PM10 nonattainment areas, South Coast and San Joaquin Valley, have the highest concentrations of ammonium nitrate in California. Tables 1 and 2 demonstrate the significant fraction of ammonium nitrate in PM10 and PM2.5 mass, respectively. Table 1, except where noted, is based on PM10 chemical composition data collected as part of the California Regional PM10/PM2.5 Air Quality Study (CRPAQS). The annual average values in Table 2 are based on routine PM2.5 chemical composition data, while 24-hour exceedance data are based on routine and CRPAQS data combined. Roughly 20 to 30 percent of the annual average PM10 mass and 30 to 40 percent of the annual average PM2.5 mass is ammonium nitrate (Tables 1 and 2). Basin-high annual average PM10 ammonium nitrate concentrations ranged from 11 μg/m^3 in the San Joaquin Valley to 27 μg/m^3 in the South Coast. The ammonium nitrate fraction is even larger on the peak PM days and was found to contribute up to 57 percent of PM10 mass and 84 percent of PM2.5 mass. Peak 24-hour average PM10 ammonium nitrate levels in the South Coast Air Basin and the San Joaquin Valley Air Basin reached over 100 μg/m^3. With respect to PM2.5, ammonium nitrate concentrations alone can exceed the federal PM2.5 standards.

Table 1. PM10 Ammonium Nitrate Fractions
(Based on 2000 CRPAQS PM10 Chemical Composition Data)

Basin	**Site Name**	**2000 Annual Average**		**PM10 Exceedance Days**		
		Conc (μg/m^3)	**% of PM10 Mass**	**# of Days**	**Ammonium Nitrate**	
					Max Conc (μg/m^3)	**Max % of PM10 Mass**
SJV	Bakersfield-Golden	10	22	1	98	47
SJV	Corcoran-Patterson	10	24			
SJV	Fresno Drummond	10	24	2	63	38
SJV	Hanford-Irwin St.	11	27	1	75	48
SJV	Modesto-14th St.	7	23			
SJV	Oildale-Manor	11	28	1	112	57
SJV	Visalia Church St.	11	25			
SC	Riverside-Rubidoux	27*	34*	3*	110	52*

* Based on 1995 PTEP monitoring conducted in the South Coast.

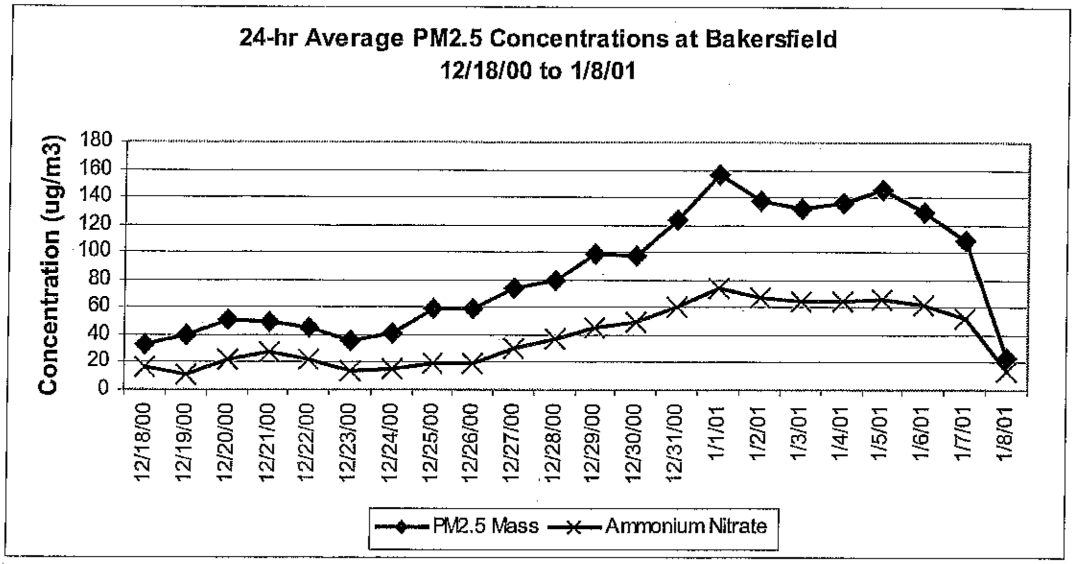
Table 2. PM2.5 Ammonium Nitrate (Based on Routine and CRPAQS PM2.5 Chemical Composition Data)

Basin	Site Name	6/1/01-5/31/02 Annual Average		PM2.5 Exceedance Days			
		Conc (µg/m^3)	% of PM2.5 Mass	# of Days	Ammonium Nitrate		
					Max Conc (µg/m^3)	% of PM2.5 Mass	
						Avg	Max
SC	Riverside-Rubidoux	15	44	8	51	59	64
SD	El Cajon	6	41	0			
SFB	San Jose-4th Street	4	24	0			
SJV	Bakersfield-California	9	33	17	78	58	67
SJV	Oildale-Manor	9	42*	8	73	61	84
SJV	Fresno-1st Street	9	32	25	72	39	73
SV	Sacramento-13th St.	3	34*	3	53	43	59

* Based on 2000 CRPAQS data.

Elevated PM concentrations can sometimes occur as isolated and localized events, but most of the time they result from a buildup of concentrations throughout the region to yield the highest PM concentrations. Figure 1 illustrates a buildup and dissolution of PM2.5 mass and ammonium nitrate concentrations at Bakersfield between December 18, 2000 and January 8, 2001. This episode resulted in record high PM10 and PM2.5 concentrations throughout Central California. Ammonium nitrate was a substantial fraction of the PM mass comprising 50 to 70 percent of the PM2.5 mass at most sites in the San Joaquin Valley. This episode represented the highest concentrations included as part of the San Joaquin Valley Air Pollution Control District's recently adopted PM10 plan and illustrates the significant role of ammonium nitrate both in the buildup and resultant exceedances of PM standards in the San Joaquin Valley.

Figure 1



Chemical Formation of Ammonium Nitrate from NOx Emissions

As discussed above, a substantial fraction of both the PM10 and PM2.5 mass in California is comprised of secondary ammonium nitrate. The formation of secondary ammonium nitrate begins with the oxidation of NOx into nitric acid. The nitric acid then reacts with gaseous ammonia to form ammonium nitrate. NOx can be oxidized into nitric acid through both daytime and nighttime reactions involving the hydroxyl radical and ozone respectively. Although VOCs can play a role in the oxidation of NOx to nitric acid, studies in the San Joaquin Valley have shown that ammonium nitrate is most responsive to reductions in NOx emissions, with minimal response to changes in VOC emissions.

Chemical Formation of Secondary Organic Aerosols from VOC Emissions

A portion of PM10 and PM2.5 in California also results from the formation of secondary organic aerosols due to the oxidation of VOCs. Atmospheric chemical reactions involving VOC species with at least seven carbon atoms can produce secondary organic aerosols. The reaction products can either form new particles, or condense onto existing particles. This process is expected to be most active during periods of high photochemical activity. Because peak PM10/PM2.5 concentrations are not well correlated with peak ozone, secondary organic aerosols do not generally comprise a large fraction of the measured carbon in either the San Joaquin Valley or the South Coast. Estimates of the fraction of carbon which is secondary in origin ranges from 20 percent of peak 24-hour exceedances in the San Joaquin Valley, to 20 to 30 percent of the annual average in the South Coast. Semi-volatile VOC species can also be directly adsorbed onto existing particles under low temperature, high humidity conditions.

Role of Carbon Monoxide in PM Formation

The simplest carbon containing molecule in the atmosphere, carbon monoxide (CO), participates in the conversion of free radicals (hydroxyl radical to hydroperoxyl radical) that enhance the oxidation of NOx to nitric acid. However, there are several other paths to the same radical conversion and the role of CO in the oxidation of NOx to nitric acid is minor in the polluted atmosphere. CO does not play a direct role in the oxidation of VOCs into secondary organic aerosls. Thus the role of CO in producing secondary particulate matter in the polluted atmosphere is minor or negligible. To our knowledge, no PM10 plan has ever included CO controls for PM.

Impact of Changes in NOx and VOC Emissions on PM10 and PM2.5 Concentrations in California

The San Joaquin Valley and South Coast have recently prepared PM10 attainment plans that demonstrate the relationship between emission changes and resulting PM concentrations and the impacts of control strategies on achieving the national ambient air quality standards for PM10. The potential impact of changes in NOx and VOC emissions on the PM10 concentrations in these two areas was estimated by following the attainment demonstration procedures contained in each plan. In the San Joaquin Valley the 24-hour PM10 standard is the most difficult to attain, while in the South Coast it is the annual standard. Therefore, the highest 24-hour design value at Bakersfield-Golden, with a 24-hour average concentration of 205 $\mu g/m^3$, was selected to evaluate the potential impacts on 24-hour concentrations, while the highest annual design value at Riverside-Rubidoux of 56.8 $\mu g/m^3$ was selected to evaluate an annual impact.

The impact on the peak 24-hour PM10 value in the San Joaquin Valley was estimated by closely following the procedure outlined in the San Joaquin Valley plan, which used both CMB modeling with grid-based photochemical aerosol chemistry modeling analysis (UAM-Aero), combined with proportional rollback to demonstrate attainment. The CMB modeling provided source apportionment for primary particles. The grid-based photochemical model provided a conversion factor for precursors into secondary particles (1.5 NOx to 1 nitrate proportionality ratio) that was then used in the proportional rollback analysis for ammonium nitrate. Rollback calculations were used to determine future compliance with the 24-hour standard by calculating the effect of emission reductions predicted for the major source categories. The incremental impact of changes in NOx and VOC emissions on PM10 due to oxygenated gasoline was estimated by changing the projected NOx and VOC emissions in the rollback analysis by 10 tons per day. The results show that while changing NOx emissions by 10 tons per day would change the peak 24-hour PM10 concentration by 1.5 ug/m^3, changing VOC emissions by the same amount would only result in a 0.14 µg/m^3 change in PM10.

The impact on the annual average PM10 concentration in the South Coast Air Basin was estimated by applying a simple linear rollback approach. Annual average PM10 total mass and composition was predicted using the UAM-LT model applied to a full year of data. The predicted PM composition data from the model results and emissions data from the 2002 Almanac were used to estimate a simple linear response to a 10 ton per day change in either VOC or NOx emissions. A conversion factor of 1 NOx to 1 nitrate was assumed in the analysis. The resulting annual average impacts were then reduced by one third as the waiver for the federal oxygenate standard would only apply for eight months of the year. The change in annual PM10 concentration from a 10-ton per day change in NOx emissions in the South Coast was again an order of magnitude larger than from the same 10 ton per day change in VOC emissions. Table 3 shows the incremental impact on PM10 concentrations in the San Joaquin Valley and the South Coast from a 10 ton per day change in NOx or VOC emissions.

Table 3. PM10 Concentration Response to 10 ton per day change in NOx and VOC Emissions

Site	PM10 Concentration Change from NOx (ug/m^3)	PM10 Concentration Change from VOC (ug/m^3)
Bakersfield Golden	1.5	.14
Riverside Rubidoux	.12	.011

Emission reductions that lower PM10 concentrations will also lower PM2.5 concentrations. Because almost all of the ammonium nitrate and secondary organic carbon can be found in the PM2.5 size fraction, the results presented for PM10 also are applicable for PM2.5.

Role of NOx Controls in Attaining PM10 and PM2.5 Standards

Both the San Joaquin Valley and South Coast attainment plans indicate that a substantial fraction of the PM10 mass is secondary ammonium nitrate formed in the atmosphere from photochemical reactions involving precursor gases. Both PM10 attainment plans indicate that reducing NOx emissions has the largest beneficial impact on ambient PM10 levels, and both plans rely strongly on NOx controls to demonstrate attainment. Although modeling in the San Joaquin Valley indicates that VOC controls are not effective in reducing secondary ammonium nitrate, they do result in a small decrease in PM10 mass due to reduction in condensable PM10 emissions from these organic compounds. Since the VOC related reductions are very small compared to NOx related reductions, the decrease in VOC emissions due to oxygenated gasoline will have a much smaller impact on PM10 concentrations than the corresponding increase in NOx emissions. The impact of NOx and VOC emissions on PM concentrations is reflected in the PM reductions projected in the attainment plans. In the San Joaquin Valley, approximately 19 $\mu g/m^3$ in PM10 reductions came from NOx controls and 2 $\mu g/m^3$ from VOC related controls (Table 4). In the South Coast, approximately 13 $\mu g/m^3$ in PM10 reductions came from NOx controls and only 0.2 $\mu g/m^3$ from VOC related controls (Table 5).

Table 4. Peak 24-hour Exceedance Composition and Controls

Site	Year	Total PM10 Concentration (ug/m^3)	Ammonium Nitrate (ug/m^3)	Secondary Organics (ug/m^3)*	Ammonium Sulfate (ug/m^3)	Other Primary (ug/m^3)
Bakersfield	2001	205	95.39	6.88	7.02	95.71
Golden	2010	152	75.90	4.90	5.10	65.60

* Assumes 50% of the mobile source and other organic carbon categories is secondary and responds to VOC control.

Table 5. Peak Annual Exceedance Composition and Controls

Site	Year	Total PM10 Concentration (ug/m^3)	Ammonium Nitrate (ug/m^3)	Secondary Organics (ug/m^3)*	Ammonium Sulfate (ug/m^3)	Other Primary (ug/m^3)
Riverside Rubidoux	1995	56.8	24.38	2.10	3.86	26.46
	2006	47.6	15.35	1.98	4.27	26.00
	2010	45.0	11.73	1.89	4.14	27.24

* Assumes that 30% of the organic carbon is secondary and therefore responds to VOC control - this is the percentage assumed in the 24-hour rollback analysis used in the South Coast attainment demonstration modeling.

Impact of Emission Changes on PM10 and PM2.5 Attainment

There are several sites in both the San Joaquin Valley and the South Coast attainment plans that demonstrate attainment of the PM10 standards by only small margins. For example, the modeling for Bakersfield-Golden predicts a PM10 concentration of 152 µg/m^3 in the 2010 attainment year, with a value of 154.5 µg/m^3 considered nonattainment. In the South Coast, the modeling predicts a PM10 concentration of 50.4 µg/m^3 at Ontario in the 2006 attainment year, with a value of 50.5 µg/m^3 considered nonattainment. Therefore, a waiver from the federal oxygenate requirement would provide an additional margin of safety in assuring attainment of the federal PM10 standards in these areas as well as facilitate more expeditious attainment.

Moreover, in order to attain the federal PM2.5 standards, significant further emission reductions beyond those specified for PM10 will be needed. For example, even with planned controls, the South Coast attainment plan estimates that Fontana will be 80 percent above the federal PM2.5 standard in 2010. Although future PM2.5 concentrations were not addressed in the San Joaquin Valley PM10 attainment plan, the impacts of controls included in the PM10 plan on PM2.5 suggest that the San Joaquin Valley could also be approximately 70 to

80 percent above the federal 24-hour PM2.5 standard in 2010. Secondary ammonium nitrate is the largest component of the PM2.5 mass, often constituting more than 50 percent of the mass. Therefore, additional reductions in NOx emissions will be essential in achieving the federal PM2.5 standards in these areas.

California Environmental Protection Agency

Air Resources Board

EVAPORATIVE EMISSIONS FROM OFFROAD EQUIPMENT

Engineering and Certification Branch
Monitoring and Laboratory Division

June 22, 2001

EVAPORATIVE EMISSIONS FROM OFFROAD EQUIPMENT

Introduction

This report summarizes the results of testing to quantify evaporative and permeation emissions from off-road equipment. The testing was performed to support a control measure to limit permeation and evaporative emissions from equipment that utilize small off-road engines. Test data were also generated to further develop the Air Resources Board's OFFROAD model. Testing was performed on a variety of equipment found in California's inventory of off-road equipment.

Testing Objectives

The primary objectives of the testing were as follows:

- Measure the non-fuel background emissions from new equipment
- Measure uncontrolled hot soak and diurnal evaporative emissions from handheld and non-handheld off-road equipment with summertime commercial pump fuel containing MTBE
- Measure uncontrolled hot soak and diurnal evaporative emissions from walk-behind lawn mowers with commercial fuel containing ethanol
- Measure uncontrolled diurnal evaporative emissions using a winter temperature profile
- Quantify the vented emissions arising from fuel tanks used with off-road equipment
- Quantify sources of evaporative emissions from fuel system components on walk-behind lawn mowers
- Measure uncontrolled and controlled fuel tank permeation emissions

Background Emissions

Our first objective was to determine the diurnal background evaporative emissions from new equipment at the point of sell. All of the equipment tested was manufactured at least one month prior to testing and did not contain fuel in their fuel systems.

Table 1 summarizes the non-fuel background emissions for six pieces of handheld and non-handheld equipment.

Table 1

Equipment Type	Manf.	Engine Type	Background (grams/day)
Chainsaw	Husqvarna	2 - Stroke	0.014
Walk Behind Mower	Toro	4 - Stroke	0.014
Leaf Blower	Echo	2 - Stroke	0.016
Walk Behind Mower	Murray	4 - Stroke	0.017
String Trimmer	Echo	2 - Stroke	0.017
Walk Behind Mower	Lawn Boy	4 - Stroke	0.026
Front Engine Tractor	Murray	4 - Stroke	0.066
		Average	0.024

Summertime Hot Soak and Diurnal Evaporative Emissions with Fuel Containing MTBE

Handheld Equipment

Table 2 summarizes the summertime hot soak and evaporative emissions for popular types of handheld equipment tested.

Table 2

Handheld Equipment					
Equipment Type	**Manf.**	**Engine Type**	**Test Condition**	**Summer Diurnal Emissions (grams/day)**	**Summer Hot Soak Emissions (grams/ 1 hour test)**
Chainsaw	Husqvarna	2 - Stroke	New	0.356	0.097
Hedge Trimmer	Echo	2 - Stroke	New	0.673	0.066
Leaf Blower	Shindaiwa	2 - Stroke	New	1.779	0.113
Leaf Blower	Stihl	2 - Stroke	New	1.500	0.163
Leaf Blower	Echo	2 - Stroke	New	1.336	0.074
			Average	**1.538**	**0.117**
			Std. Dev.	**0.224**	**0.045**
String Trimmer	Honda	4 - Stroke	New	0.715	0.071
String Trimmer	Echo	2 - Stroke	New	0.907	0.080
			Average	**0.811**	**0.076**

Handheld Equipment

Table 3 summarizes the summertime hot soak and evaporative emissions for popular types of handheld equipment tested. Data for equipment types with an asterisk were not used in the calculation of the group average or standard deviation.

Table 3

Non-Handheld Equipment

Equipment Type	Manf.	Engine Type	Test Condition	Summer Diurnal Emissions (grams/day)	Summer Hot Soak Emissions (grams/ 1 hour test)
Lawn Mower*	MTD	4 - Stroke	Used	0.197	0.052
Lawn Mower	Lawn Boy	4 - Stroke	New	2.068	0.412
Lawn Mower	Craftsman	4 - Stroke	New	2.181	0.580
Lawn Mower	Craftsman	4 - Stroke	New	2.256	0.546
Lawn Mower	Yard Machine	4 - Stroke	New	2.289	0.406
Lawn Mower	Yard Machine	4 - Stroke	New	2.446	0.614
Lawn Mower	Yard Machine	4 - Stroke	New	2.450	0.632
Lawn Mower	Honda	4 - Stroke	New	2.495	0.475
Lawn Mower*	Toro	4 - Stroke	New	5.746	0.699
Lawn Mower*	Murray	4 - Stroke	New	8.765	2.177
			Average	**2.312**	**0.524**
			Std. Dev.	**0.159**	**0.093**
Lawn Mower	Murray	4 - Stroke	Used	4.123	0.699
Lawn Mower	Murray	4 - Stroke	Used	7.064	0.528
			Average	**5.594**	**0.614**
			Std. Dev.	**2.080**	**0.121**
Generator	Tsurumi	4 - Stroke	Used	7.392	2.358
Generator	Coleman	4 - Stroke	Used	15.045	2.721
			Average	**11.219**	**2.540**
			Std. Dev.	**5.411**	**0.257**
Front Engine Tractor	Murray	4 - Stroke	New	5.949	1.251
Rear Engine Tractor	Snapper	4 - Stroke	New	7.142	1.216
Front Engine Tractor	Toro	4 - Stroke	Used	13.015	2.093
			Average	**8.702**	**1.520**
			Std. Dev.	**3.782**	**0.497**
Edger	Honda	4 - Stroke	New	1.204	1.356
Edger	B&S	4 - Stroke	Used	1.846	0.373
			Average	**1.525**	**0.865**
			Std. Dev.	**0.454**	**0.695**
Tiller	Maxim	4 - Stroke	Used	4.123	0.571

Summertime Hot Soak and Diurnal Evaporative Emissions with Fuel Containing Ethanol

In an effort to gauge the emissions from fuel containing ethanol, hot soak and diurnal evaporative tests were repeated on five walk-behind mowers. Prior to testing, the fuel systems of the mowers were drained and refilled with fuel containing ethanol. They were then soaked for thirty days. After the soak period, the aged fuel was drained, and the mowers were filled to 50% capacity. The hot soak and diurnal tests were performed immediately after refueling. Tables 4 detail the results of the testing.

Table 4

	Commercial Pump Fuel Containing MTBE		**Commercial Pump Fuel Containing Ethanol**	
Exhaust Emission Compliant Mowers	**Hot Soak Emissions (grams/test)**	**Diurnal Emissions (grams/day)**	**Hot Soak Emissions (grams/test)**	**Diurnal Emissions (grams/day)**
Honda HRR 216	0.475	2.495		
Toro 20040	0.699	5.746	0.769	7.274
Lawn Boy 10363	0.412	2.068		
Yard Machine 11A-021C000	0.406	2.289	0.573	3.207
Yard Machine 12A-559K401	0.614	2.446		
Yard Machine 11A-089S700	0.632	2.450	1.163	3.356
Craftsman 917379440	0.580	2.181	0.858	3.266
Craftsman 917389580	0.546	2.256	0.677	3.287
Average	**0.546**	**2.741**	**0.808**	**4.078**
Std. Dev.	**0.106**	**1.223**	**0.225**	**1.787**
Average Emissions Increase			**47.99%**	**48.81%**

Wintertime Diurnal Evaporative Emissions

In an effort to measure wintertime diurnal emissions, diurnal evaporative tests were repeated on five pieces of handheld and non-handheld equipment using a winter temperature profile (attachment 2). Table 5 documents the significant reduction in evaporative emissions when using a winter profile.

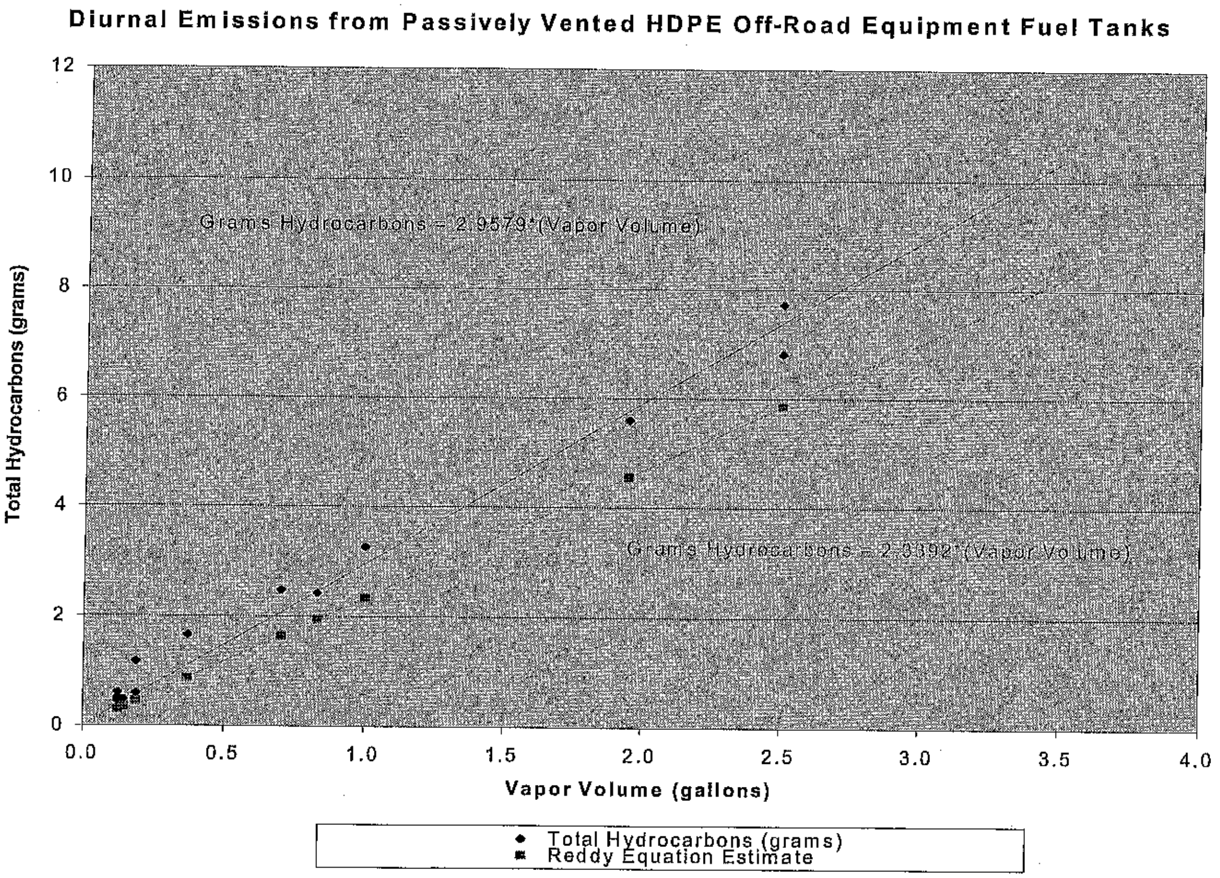
Table 5

Equipment Type	Diurnal Emissions Summer (grams/day)	Diurnal Emissions Winter (grams/day)
Coleman Generator	15.045	3.573
Murray Front Engine Tractor	5.949	2.239
Craftsman Walk Behind Mower	2.256	0.895
Shindaiwa Leaf Blower	1.779	0.526
Echo String Trimmer	0.907	0.322

Vented Emissions from SORE Fuel Tanks

In general, the vented emissions from automobile fuel tanks can be expected to follow the Reddy Equation. The Reddy equation estimates the diurnal emissions in grams for a particular vapor volume for a given rise in fuel temperature for a fuel with known Reid vapor pressure (RVP). The purpose of the fuel tank vented emission testing was to generate empirical data based on SHED testing to quantify fuel tank vented emissions. An analysis of the empirical data led us to derive a general equation for passively vented non-metallic off-road equipment fuel tanks.

The following chart compares ARB empirical data and Reddy equation estimates for fuel tank vented emissions:



The above graph suggests that large fuel tanks are a significant source of evaporative emissions. A typical 5 gallon fuel tank filled to 50% capacity can be expect to emit over 7 grams of hydrocarbons in a 24-hour summer diurnal cycle. Table 6 provides information on vented emissions from all fuel tanks tested.

Table 6

Category	Equipment Manufacturer	Model	Tank Type	Passively Vented	Tank Volume (gallons)	Vapor Volume (gallons)	Tank Vented (grams/day)
Leaf Blower	Echo	PB-231	HDPE	No	0.16	0.08	0.042
Hedge Trimmer	Echo	HC 1500	HDPE	No	0.08	0.04	0.080
Leaf Blower	Shindaiwa	EB 500	HDPE	No	0.55	0.275	0.081
String Trimmer	Honda	UMK 431	HDPE	No	0.12	0.06	0.192
String Trimmer	Echo	SRM-261	HDPE	No	0.15	0.075	0.296
Walk Behind Mower	Yard Machine	12A-559K401	HDPE	Yes	0.25	0.125	0.443
Walk Behind Mower	Craftsman	917379440	HDPE	Yes	0.25	0.125	0.443
Walk Behind Mower	Honda	HR 216	HDPE	Yes	0.29	0.145	0.477
Walk Behind Mower	Yard Machine	11A-089S700	HDPE	Yes	0.25	0.125	0.499
Walk Behind Mower	Lawn Boy	10363	HDPE	Yes	0.38	0.19	0.589
Walk Behind Mower	Yard Machine	11A-021C000	HDPE	Yes	0.25	0.125	0.596
Edger	Power Trim	208 H	Metal	Yes	0.37	0.185	1.143
Walk Behind Mower	Craftsman	917389580	HDPE	Yes	0.38	0.19	1.166
Tiller	Maxim	OO-RMT50B	HDPE	Yes	0.74	0.37	1.654
Leaf Blower	Stihl	BR 320	Nylon	No	0.38	0.19	2.171
Rear Engine Tractor	Snapper	M301019BE	HDPE	Yes	1.66	0.83	2.429
Front Engine Tractor	Murray	40508X92	HDPE	Yes	1.4	0.7	2.485
Commercial Turf	BCS	730	Nylon	Yes	2.0	1.0	3.264
Welder	Multiquip	ACX140	Metal	Yes	1.29	0.645	3.473
Front Engine Tractor	Toro	72045	HDPE	Yes	3.9	1.95	5.592
Walk Behind Mower	Toro	20040	HDPE	Yes	0.50	0.25	6.091
Commercial Turf	Toro ProLine	30177	HDPE	Yes	5.0	2.5	6.814
Tractor	Toro	3100	HDPE	No	7.5	3.75	7.262
Generator	Coleman	PowerBase 5000	HDPE	Yes	5.0	2.5	7.724

Sources of Evaporative Emissions from Walk-Behind Mowers

In order to quantify the emissions from fuel system components (carburetor, fuel line, and fuel tank), total system and separate fuel tank (vented and permeation) emissions were measured for eight walk-behind lawn mowers. The fuel tank emissions were measured using OEM replacement tanks and caps.

Fuel Tank Vented Emissions

Fuel tank vented emission tests were performed on new non-preconditioned fluorinated (controls permeation) tanks. Prior to diurnal testing, the tanks were prepped by sealing the fuel outlets with HDPE coupons, filling them to 50% capacity with commercial fuel containing MTBE, and capping them with OEM fuel caps. After prepping, each tank underwent a 24-hour diurnal test using a summer temperature profile.

Fuel Tank Permeation Emissions

Fuel tank permeation emission tests were performed on preconditioned (presoaked with fuel for 30 days) untreated tanks. After preconditioning, tanks were drained, refilled with certification fuel, and sealed with HDPE coupons in place of the OEM fuel caps. The tanks then underwent multiple 24-hour diurnal cycles in a SHED using the summer temperature profile. At the end of each diurnal cycle, each tank was weighed on a balance. When the weight loss for each tank had stabilized (standard deviation less than 0.25 grams) for five consecutive days, the average permeation rate was calculated according to ARB test method 513.

Calculated Carburetor and Fuel Line Emissions

The carburetor and fuel line contribution to total diurnal emissions was estimated by subtracting measured fuel tank vented and permeation emissions from the total diurnal emissions measured for a complete lawn mower. Additionally, separate diurnal tests were performed on three carburetors and two fuel lines to validate the calculated emissions from carburetors and fuel lines. Table 7 shows the results of testing to quantify components of diurnal emissions from walk-behind lawn mowers.

Table 7

Mower Model	Diurnal Emissions (grams/day)	Fuel Tank Vented Emissions (grams/day)	Fuel Tank Permeation Emissions (grams/day)	Calculated Carburetor/Fuel Line Emissions (grams/day)	Carburetor Measured (grams/day)	Fuel Line Measured (grams/day)
Lawn Boy 10363	2.068	0.589	0.62	0.86		
Craftsman 917389580	2.256	1.166	0.47	0.62		
Yard Machine 11A-021C000	2.289	0.596	0.34	1.35	0.993	0.373
Yard Machine 12A-559K401	2.446	0.443	0.51	1.49	1.590	0.495
Yard Machine 11A-089S700	2.450	0.499	0.53	1.42		
Honda HRR 216	2.495	0.477	0.66	1.36	1.476	
Craftsman 917379440	2.181	0.443	0.65	1.09		
Toro 20040	*5.746	*6.091	0.74			
Average	**2.312**	**0.602**	**0.57**	**1.17**	**1.353**	**0.434**
Std. Dev.	**0.159**	**0.063**	**0.128**	**0.33**	**0.317**	**0.086**

Note: The Toro fuel tank vented emissions were suspect and not used in the calculated averages.

Permeation Testing

Fuel tank permeation data were generated for a variety of treated and untreated handheld and non-handheld equipment. The permeation testing followed ARB test method 513 except that they did not undergo durability testing. Table 8 provides of summary of the permeation testing.

Table 8

Mfg.	Test Fuel	Fuel Density (grams/gal)	Treatment	Result (grams/gal/day)	Group Average	% Reduction Due to Treatment	% Permeation Increase Due to Ethanol
Husvarna Chainsaw	CERT Mix	2810	Untreated	1.31			
Exmark Metro Mower	CERT	2791	Untreated	0.55			
Murray Front Engine Tractor	CERT	2791	Untreated	1.27			
Murray Front Engine Tractor	Ethanol	2828	Fluorinated	0.00		100%	
Snapper Rear Engine Tractor	CERT	2791	Untreated	0.67			
Snapper Rear Engine Tractor	Ethanol	2828	Fluorinated	0.01		99%	
Toro Tractor	CERT	2791	Untreated	0.77			
Toro Tractor	CERT	2791	Untreated	0.88	0.82		
Toro Tractor	Ethanol	2828	Untreated	0.87			6%
Toro Proline Mower	CERT	2791	Untreated	0.77			
Toro Greens Mower	CERT	2791	Untreated	0.35			
Coleman Generator	CERT	2791	Untreated	0.64			
Coleman Generator	Comm. Pump	2807	Fluorinated	0.00		99%	
Echo Hedge Trimmer	CERT Mix	2810	Untreated	3.42			
Shindawia Leaf Blower	CERT Mix	2810	Untreated	2.26			
Stihl Leaf Blower	CERT Mix	2810	Untreated	0.72			
Echo Leaf Blower	CERT Mix	2804	Untreated	1.88			
Maxim Tiller	CERT	2791	Untreated	2.46			
Honda Mower	CERT	2791	Untreated	4.57			
Toro Mower	CERT	2791	Untreated	2.44			
Toro Mower	Comm. Pump	2807	Untreated	2.97			
Toro Mower	Ethanol	2828	Untreated	3.31			36%
Lawn Boy Mower	CERT	2791	Untreated	3.59			
Lawn Boy Mower	Ethanol	2828	Fluorinated	0.56		84%	
Lawn Boy Mower	Comm. Pump	2807	Untreated	3.25			
Yard Machine Mower	Ethanol	2828	Untreated	3.71			
B&S Quantum	CERT	2791	Untreated	5.56			
B&S Quantum	CERT	2791	Untreated	5.17	5.37		
B&S Quantum	Ethanol	2828	Untreated	5.88			
B&S Quantum	Ethanol	2828	Untreated	5.71	5.79		8%
Honda Trimmer	CERT	2791	Untreated	4.23			
Echo String Trimmer	CERT Mix	2804	Untreated	3.09			

Table 8 Continued

Toro Tractor	CERT	2791 Untreated	1.05			
Tecumseh Tank	CERT	2791 Untreated	2.52			
Tecumseh Tank	CERT	2791 Untreated	2.54	2.53		
Tecumseh Tank	Comm. Pump	2807 Untreated	3.38			
Tecumseh Tank	Comm. Pump	2807 Untreated	2.74	3.06		
Tecumseh Tank	Ethanol	2828 Untreated	2.94			
Tecumseh Tank	Ethanol	2828 Untreated	3.43	3.19		26%
FHP (530-049393)	CERT Mix	2804 Untreated	2.74			
FHP (530-038592)	CERT Mix	2804 Untreated	2.94			
FHP (530-038592)	Ethanol Mix	2838 Untreated	5.11			42%
FHP (530-049318)	CERT Mix	2804 Untreated	2.08			
FHP (530-049318)	Ethanol Mix	2838 Untreated	3.92			47%
FHP (530-052343)	CERT Mix	2804 Untreated	3.00			
FHP (530-052343)	Ethanol Mix	2838 Untreated	5.57			46%
Yard Machine Mower	CERT	2791 Untreated	2.74			
Yard Machine Mower	Ethanol	2828 Untreated	3.80			39%
Yard Machine Mower	CERT	2791 Untreated	4.08			
Yard Machine Mower	Ethanol	2828 Untreated	4.28			5%
Craftsman Mower	CERT	2791 Untreated	4.40			
Craftsman Mower	Ethanol	2828 Fluorinated	0.51		88%	
Craftsman Mower	Comm. Pump	2807 Untreated	5.22			
Craftsman Mower	CERT	2791 Untreated	2.32			
Craftsman Mower	Ethanol	2828 Fluorinated	1.14		51%	
Craftsman Mower	Comm. Pump	2807 Untreated	2.45			
Yard Machine Mower	Comm. Pump	2807 Untreated	4.25			
Yard Machine Mower	CERT	2791 Untreated	3.60			
Stihl Leaf Blower	CERT Mix	2804 Untreated	0.21			
Tecumseh Tank	CERT	2791 Sulfonated	2.72			
Tecumseh Tank	CERT	2791 Sulfonated	2.78			
Tecumseh Tank	CERT	2791 Sulfonated	2.71			
Tecumseh Tank	CERT	2791 Sulfonated	2.94	2.79		
B&S Quantum	CERT	2791 Sulfonated	2.94			
B&S Quantum	Ethanol	2828 Sulfonated	2.91			No Increase
Tecumseh Tank	Ethanol	2828 Sulfonated	2.90		No Reduction	
Tecumseh Tank	Ethanol	2828 Sulfonated	0.71		75%	
Tecumseh Tank	Ethanol	2828 Sulfonated	2.69		4%	
Tecumseh Tank	Ethanol	2828 Sulfonated	3.71		No Reduction	
Tecumseh Tank	Ethanol	2828 Sulfonated	1.50		46%	
Tecumseh Tank	Ethanol	2828 Sulfonated	0.24		91%	
Tecumseh Tank	Ethanol	2828 Sulfonated	1.99	1.96	29%	

Notes:
Each row represents a unique test.
Tanks of the same model are grouped together.
Emission reductions due to treatment compares tests performed with certification fuel to tests with a treated tank.

Conclusions

The following important generalizations are based on an analysis of the above test results:

- Non-fuel related background emissions are insignificant
- Diurnal evaporative emissions are lower for handheld equipment when compared to non-handheld equipment
- Handheld equipment has significant evaporative emissions
- New walk-behind mowers typically emit between 2.1 and 2.5 grams total hydrocarbons in a summer diurnal cycle
- Evaporative emissions increase significantly (approximately 49%) when equipment is operated with fuel containing ethanol
- Wintertime diurnal emissions are significantly lower than summer emissions
- The emissions from passively vented HDPE fuel tanks follow a predicable function and are significant
- Evaporative and permeation emissions from walk-behind mowers account for roughly 50% of the total system emissions
- Fluorination is effective in reducing permeation emissions

Attachment 1

1 Day / 24 Hour / 1440 Minute Summer Variable Temperature Profile

HOUR	MINUTE	TIME REMAINING (MINUTES)	TEMPERATURE (°F)
0	0	1440	65.0
1	60	1380	66.6
2	120	1320	72.6
3	180	1260	80.3
4	240	1200	86.1
5	300	1140	90.6
6	360	1080	94.6
7	420	1020	98.1
8	480	960	101.2
9	540	900	103.4
10	600	840	104.9
11	660	780	105.0
12	720	720	104.2
13	780	660	101.1
14	840	600	95.3
15	900	540	88.8
16	960	480	84.4
17	1020	420	80.8
18	1080	360	77.8
19	1140	300	75.3
20	1200	240	72.0
21	1260	180	70.0
22	1320	120	68.2
23	1380	60	66.5
24	1440	0	65.0

Attachment 2

1 Day / 24 Hour / 1440 Minute Winter Variable Temperature Profile

HOUR	MINUTE	TIME REMAINING (MINUTES)	TEMPERATURE (°F)
0	0	1440	51.6
1	60	1380	50.5
2	120	1320	49.9
3	180	1260	49.3
4	240	1200	49.0
5	300	1140	48.7
6	360	1080	48.5
7	420	1020	49.3
8	480	960	52.8
9	540	900	58.0
10	600	840	62.5
11	660	780	65.9
12	720	720	68.2
13	780	660	69.1
14	840	600	69.5
15	900	540	69.1
16	960	480	67.2
17	1020	420	63.6
18	1080	360	59.9
19	1140	300	57.4
20	1200	240	55.9
21	1260	180	54.6
22	1320	120	53.5
23	1380	60	53.0
24	1440	0	51.6

Test Protocol and Results for the Determination of Permeation Rates from High Density Polyethylene Containers & Barrier Surface Treatment Feasibility Study

Introduction

Air Resources Board staff tested several High Density Polyethylene (HDPE) and metal portable fuel containers (containers) to determine average permeation rates and to assess the effectiveness of several barrier surface treatments. Barrier treatments included sulfonation and two levels of fluorination. Containers were subjected to a variable temperature profile and permeation rates determined gravimetrically. Both CERT fuel and gasoline containing 5% ethanol were used during the test. In all, over 50 portable fuel containers were tested over a period of several months. Containers selected for testing were purchased at retail outlets located throughout California, except for one particular type (Vemco, 1.25 gallon) that at present is only available through mail order. The test containers ranged in size from 1.25 gallons to 6.6 gallons and all initial tests were performed in duplicate.

Test Protocol

All containers selected for testing were preconditioned with fuel for a period of four weeks, minimum. During the preconditioning cycle containers were stored at ambient temperature and pressure in flammable storage cabinets. After a minimum of four weeks preconditioning, the containers were emptied, blown dry with compressed zero air, and immediately refilled with CERT fuel (see Attachment 1). CERT fuel was selected to minimize variation of the permeation results due to variations in fuel properties.

Each container was then sealed using a combination of metal filled epoxy with an overcoat of a special non-permeable two-part epoxy resin (SealPak CS3204 A1/2 Sealant). Where possible, plastic caps and plugs were removed from the containers and replaced with metal plugs and caps. All secondary vents were tapped and plugged with 1/8" brass fittings and coated with sealant.

After allowing sufficient time for the curing of all sealant, the containers were tested for leaks. Containers were heated and when positive pressure was observed (container swelling) a hydrocarbon analyzer was used to 'snoop' the seals. Suspect containers were immersed in a water bath while under positive pressure to determine leak points. All leak points were repaired prior to any gravimetric analysis. During the diurnal tests, all suspect containers were checked with the hydrocarbon analyzer and if necessary, repaired using the same methods.

Weight loss was used as the basis for determining relative permeation rates. Sealed containers were weighed using a high capacity balance (Sartorius Masterpro, 16k-gram capacity, sensitivity ± 0.1 gram) just prior to the start of each diurnal cycle. After each container was individually weighed and the weight recorded, they were placed in a

Sealed Housing for Evaporative Determination (SHED) and exposed to a 1-day / 24-hour/ 1440-minute variable temperature profile (see Attachment 2). Containers were then post weighed after the 24-hour diurnal cycle and the weight loss calculated.

Cumulative weight loss by the containers as a function of time was plotted for all initial 24-hour test cycles. Data were considered acceptable when weight loss became linear with respect to time. All test data include the following information: calculated wetted surface area, average wall thickness, weight lost per test (± 0.1 gram), and initial volume of test fuel. Container identification labels are described in Attachment 3.

In order to determine the durability of the barrier surface treated containers, secondary tests were conducted approximately one month after the initial tests. Staff was concerned that the barrier surface might be susceptible to degradation as the containers continually swelled and paneled during testing. At the conclusion of the initial tests, several containers were randomly selected and stored intact with their original CERT fuel. Prior to the start of the secondary tests the containers were emptied, blown dry with compressed zero air, and immediately refilled with fresh CERT fuel. Adhering to the previously mentioned test protocol, approximately two weeks of diurnal data were collected and compared with initial test data. (**Note:** due to scheduling conflicts one 48 hour and two 72-hour runs were used during this phase of testing with the 1-day variable temperature profile automatically reinitiated every 24-hours).

Staff also had significant interest in any differences an alcohol based oxygenated fuel might exhibit, with respect to average permeation rates, verses an ether based oxygenated fuel. As such, staff obtained a sample of CERT fuel without Methyl Tertiary Butyl Ether (MTBE) and instead blended a similar amount of fuel grade ethanol (see Attachment 4). A sample of the fuel was submitted for analysis and the results show a percent mass of ethanol of 5.27 (see Attachment 5). This fuel was then used in both treated and untreated containers adhering to the previously mentioned test protocol.

Results

The average permeation rate from untreated containers was determined to be 1.57 grams/gallon/day. This rate is based on data averaged from tests of 13 individual containers and represents a total of 188 individual 24-hour diurnal cycles. Container sizes for all tests ranged from 1.25 gallons to 6.6 gallons.

The average permeation rate from initial tests of containers fluorinated at level 5 was determined to be 0.53 grams/gallon/day. This rate increased during secondary tests to 0.69 grams/gallon/day for an overall average rate of 0.61 grams/gallon/day. This final rate is based on data averaged from tests of 12 containers and represents a total of 266 individual 24-hour diurnal cycles.

The average permeation rate from initial tests of containers fluorinated at level 3 was determined to be 0.42 grams/gallon/day. This rate increased during secondary tests to 0.93 grams/gallon/day for an overall average rate of 0.68 grams/gallon/day. This final rate is based on data averaged from tests of 14 containers and represents a total of 262 individual 24-hour diurnal cycles.

The average permeation rate from initial tests of sulfonated containers was determined to be 1.39 grams/gallon/day. This rate is based on data averaged from tests of 11 containers and represents 160 individual 24-hour diurnal cycles. No secondary tests were performed on the sulfonated containers.

The average permeation rate from metal containers was determined to be 0.06 grams/gallon/day. This rate is based on data averaged from 3 containers and represents a total of 48 individual 24-hour diurnal cycles.

The average permeation rate from untreated containers filled with the ethanol based oxygenated fuel was determined to be 2.28 grams/gallon/day. This rate is based on data averaged from tests of 8 containers and represents a total of 100 individual 24-hour diurnal cycles.

The following table best illustrates the permeation test results. Please note that the average untreated container permeation rate is used as a baseline for determining the efficiency of the barrier surface treated and metal containers.

Table 1

Initial Tests		Secondary Tests		Overall	
Container Type	Average Rate (g/gal/day)	Container Type	Average Rate (g/gal/day)	Combined Average (g/gal/day)	Control Efficiency (%)
Untreated	1.57	Untreated	N/A	1.57	0
Fluorinated Level 5*	0.53	Fluorinated Level 5	0.69	0.61	61.2
Fluorinated Level 3	0.42	Fluorinated Level 3	0.93	0.68	57.0
Sulfonated**	1.39	Sulfonated	N/A	1.39	11.4
Metal	0.06	Metal	0.06	0.06	96.2
Ethanol Oxygenate	N/A	Ethanol Oxygenate	2.28	2.28	N/A

* Wedco & Blitz containers may be treated incorrectly, follow up tests scheduled for June '99.
** All Containers may be treated incorrectly, follow up tests scheduled for June '99.

It should be noted that not all data points recorded in the attached data sheets were used in determining the various average permeation rates. Several data points were not included in the overall calculations for reasons identified in the field data sheets. These include but are not limited to: balance errors, excessive weight loss due to incompletely cured sealant(s), and mechanical difficulties with the SHED.

Conclusions

The average permeation rate for untreated containers is 1.57 grams/gallon/day based on exposure to a standard variable temperature profile (see Attachment 2). This permeation rate correlates closely with previous tests performed by several of the resin manufacturers.

Staff has serious doubts about the suitability of fluorination as a viable barrier surface treatment. While fluorinated containers initially provide a substantial reduction in permeation rates as compared to the untreated containers, it seems that continued swelling and paneling of the container walls degrades the integrity of the barrier surface treatment. As the data in Table 1 shows, the increase in permeation rates from the initial tests with respect to the secondary tests one month later is greater than 23 % for the level 5 treated containers and greater than 54% for the level 3 treated containers. These data suggest that fluorinated barriers may not provide sufficient longevity to be considered a permanent solution. Changing container geometry to mitigate it's ability to swell and panel may alleviate this particular problem.

Some issues concerning the treatment of the level 5 verses the level 3 containers are obvious when reviewing the data (Wedco & Blitz containers, level 5 verses level 3). It was anticipated that the level 5 treated containers would have a much lower permeation rate than the level 3 containers. However, for several containers this was not the case. Research into this anomaly has determined that the suspect containers may not have been properly treated (the possibility exists that a mechanical error in the treatment equipment may be at fault). The company that performed the barrier surface treatments has agreed to treat another set of the containers in question and staff will perform further testing after the containers have undergone sufficient preconditioning.

Again, looking at the data in Table 1, the sulfonated containers had an average permeation rate almost identical to the untreated containers. Previously documented tests using sulfonated containers suggests that perhaps an error occurred during treatment. Staff contacted the company that treated these containers and learned that due to a communications error, the wrong type of sulfite gas was used during the treatment process. The company has agreed to treat another set of containers and staff will perform further testing after these containers have undergone sufficient preconditioning. Therefore, the test results of the sulfonated containers are deemed inconclusive at this time.

Based on both the initial and follow up tests, metal containers do not permeate as compared to HDPE containers.

Alcohol based oxygenated fuel increases permeation rates of the untreated containers by more than 60%. This could be significant if a change in fuel formulation is required due to the elimination of MTBE.

In conclusion, permeation from HDPE containers contributes significantly to the overall hydrocarbon emissions associated with the use of these products. While permeation emissions from one container may seem insignificant, in the aggregate they contribute significantly to California's Air Quality problems. Additionally, further testing is required to determine the efficacy of existing barrier surface treatment technologies.

FINAL REPORT

ANALYSIS OF THE PRODUCTION OF CALIFORNIA PHASE 3 REFORMULATED GASOLINE WITH AND WITHOUT AN OXYGEN WAIVER

Submitted to

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

1200 Pennsylvania Avenue, N.W.
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Under

EPA Purchase Order 0W-2026-NASX

By

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January 19, 2001

1. INTRODUCTION AND SUMMARY

MathPro Inc. is pleased to submit this draft report to the U.S. Environmental Protection Agency, Office of Transportation and Air Quality (OTAQ), pursuant to EPA Purchase Order 0W-2026-NASX (September 22, 2000).

EPA commissioned this study to support its consideration of the California Air Resources Board's (CARB) request for a waiver of the oxygen content requirement in federal (and hence most California) reformulated gasoline (RFG).

The objective of the study was to estimate

- The average physical properties of California Phase 3 RFG (CaRFG3) with and without the oxygen waiver;
- The shares of ethanol-blended and non-oxygenated CaRFG3 if the oxygen waiver were granted; and
- The oxygen content (i.e., 2.0 wt% or 2.7 wt%) of ethanol-blended CaRFG3 with and without the oxygen waiver.

The most reliable and credible method for developing such estimates is refinery LP modeling. Refinery LP modeling captures the interactions between the technical and economic aspects of refining and simulates operations of the refining sector in response to economic and regulatory driving forces. In this study, we used our proprietary refinery LP modeling system (ARMS) to simulate cost-minimizing operations of the California refining sector (in the Summer season) in meeting demands for refined products, with and without an oxygen waiver.

Exhibit 1 (immediately following the text of the report) summarizes, for the eight (8) scenarios considered, results of the analysis of primary interest to EPA: (1) estimated properties of the Summer CaRFG3 pool, with and without an oxygen waiver in place; and (2) estimated volume shares of ethanol-blended and non-oxygenated CaRFG3 in the Summer, with a waiver in place.

Our analysis also indicates that, with an oxygen waiver, the refining economics of ethanol blending at 2.0 wt% and 2.7 wt% in the Summer are too close to call, given the premises and assumptions of this study. Our analysis shows a small, but not significant, cost advantage for the higher ethanol volume. In practice, the choice between the two levels of ethanol blending would depend on many economic and technical factors.

The balance of the report comprises five sections. Section 2 discusses the rationale for the study. Section 3 lays out the methodology (including key premises). Section 4 defines the scenarios analyzed. Section 5 deals with the results of the analysis. Section 6 lists references.

2. PRIOR ANALYSES

Prior to this study, MathPro Inc. had produced estimates of gasoline pool properties and ethanol usage as part of analyses of the prospective economics of California's ban on MTBE blending [Refs. 1, 2, 3, and 4]. These analyses focused on the technical implications and costs of the various alternatives to MTBE blending. They were not commissioned or designed to assess the likely effects of an oxygen waiver on vehicle emissions.

Moreover, the prior analyses did not have the benefit of new analytical elements, data, and improvements now in our refinery LP modeling system (ARMS), such as:

- The actual CaRFG3 program (and the Beta 3 Predictive Model) – rather than the CaRFG*2* program or provisional versions of the CaRFG*3* program;
- Estimates of prospective supplies and prices of crude oil and imported gasoline blendstocks (e.g., ethanol, alkylate, and isomerate) that reflect recent analyses and forecasts;
- Technical data on key blending properties of certain blendstocks – including ethanol and various alkylate streams;
- Estimates (consistent with measurement tolerances published by CARB) of the average minimum "property deltas" used by California refiners in certifying gasoline batches with the Predictive Model;
- Representation of the property deltas as variables rather than as constants; and
- Representation of the Unocal patents on RFG blending.

All of these elements are incorporated in this analysis.

3. METHODOLOGY

We used refinery LP modeling to represent aggregate operations of the gasoline-producing refineries in California in the Summer season, with and without an oxygen waiver in place. We analyzed eight scenarios (discussed in Section 3.3); each scenario represents a unique combination of policy (e.g., waiver/no waiver) and technical factors. In each scenario, we represented the California sector meeting a specified set of product demands at minimum cost.

3.1 Enhancements to the California Refining Model

For this analysis, we enhanced the aggregate refining model used in our prior studies of the California refining sector. This section summarizes the most important enhancements.

3.1.1 Economic Data Elements

We updated economic data elements to sharpen the representation of the economics governing refinery investments and operations in the wake of an MTBE ban.

- Updated capital cost and capital charge factors to 2000 $s.
- Changed the investment location factor for California from 1.2 to 1.35.
- Reduced from 15% to 10% the after-tax return on capital investment for new capacity.
- For expanding and debottlenecking certain units, set (1) on-site unit investment costs at 50% of those for grass roots units and (2) off-site investments at zero.

3.1.2 CARB Phase 3 Predictive Model (Beta 3)

We modified the model to (1) bring the Beta 3 Predictive Model into the analysis and (2) simulate how refiners use the Predictive Model for certifying batches of CARB gasoline – flat limits (for the most part), variable compliance margins, and grade-specific certification. None of our previous analyses incorporated these elements.

- Estimated reduced form versions of the Beta 3 Predictive Model (analogous to our representation of the Phase 2 Predictive Model), in each of six variants:

  -- Flat limits (for 0, 1.8-2.2, and 2.7 wt% oxygen)
  -- Averaging (for 0, 1.8-2.2, and 2.7 wt% oxygen)

- Extended the LP model formulation so that the Predictive Model applies to individual gasoline grades (e.g., regular, premium) within each gasoline class (e.g., ethanol-blended CaRFG3, non-oxygenated CaRFG3).
- Extended the LP model formulation to treat refiners' reported compliance margins ("property deltas") as endogenous variables, with lower bounds equal to CARB's enforcement tolerances.

3.1.3 Ethanol-Related Data Elements

The first of the two changes listed below expressed ethanol price as a function of net supply available to California. The second endowed the refinery model with blending data embodied in the CARBOB Version of the Beta 3 Predictive Model and sharpened the representation of ethanol blending (especially its effect on T_{50}).

- Incorporated estimated ethanol prices (CIF California) for both California-only and national bans on MTBE blending.

- Revised ethanol blending properties (especially the T_{50} depression) to match the values incorporated in the CARBOB Version of the Beta 3 Predictive Model.

3.1.4 Representation of Key Gasoline Blendstocks

We modified the properties of certain gasoline blendstocks to incorporate newly-obtained data and, more importantly, to improve the refinery model's representation of certain operating and blending practices in the California refining sector aimed at compliance with CARB RFG standards.

- Revised certain blending properties of FCC naphtha and alkylate, based on review of existing values and published information.

- Revised and extended the representation of FCC naphtha streams.
  - Changed distillation cut-points and sulfur distribution factors for FCC naphtha fractions.
  - Represented additional dispositions for heavy FCC naphtha: hydrocracking and distillate blending (jet and diesel fuel).
  - Extended representation of FCC naphtha splitting to apply to all variants of FCC naphtha.

- Revised and extended representation of alkylate streams.
  - Improved the distillation curves for C_3 and C_4 alkylates.
  - Changed blending properties of C_5 alkylate to reflect presence of mixed C_5 paraffins (unreacted feed plus by-product material).
  - Represented alkylate splitting for T_{90} control and set alkylate cut-point for T_{90} control.

3.1.5 Blending Constraints Imposed by Unocal Patents

We extended the model formulation to represent, by gasoline grade within class, the blending practices needed to avoid infringement of the Unocal '393 patent.

This extension comprises a set of constraints on gasoline blend properties to ensure that they do not infringe on the Unocal patent. The constraints are more binding (i.e., impose higher costs of compliance) for premium gasoline than for regular.

3.1.6 Technical and Economic Data

We revised estimates of the prices and supplies of crude oil and key gasoline blendstocks.

- Updated price estimates for crude oil, alkylate, and other refinery inputs.

- Updated estimates of potential supplies to the California refining sector of iso-octane, alkylate streams, and C_6 isomerate.

3.2 Representation of Gasoline Sulfur Control

The representation in the refining model of the processes used to achieve gasoline sulfur control is a crucial element of the analysis.

- ➢ The specification of sulfur control technology can influence the preferred level of ethanol blending – 2.0 wt% or 2.7 wt% oxygen.
- ➢ Careful representation of gasoline sulfur control is essential to minimizing "over-optimization" in the refinery modeling. (Over-optimization is discussed in Section 5.2.4).

In the Predictive Model, sulfur control is the primary means of achieving NOx emission reductions and contributes to VOC emission reduction. Depending on the technology of choice, sulfur control can have the side effect of reducing the olefins content of the gasoline pool. In the Predictive Model, reducing olefins content (all else equal) reduces NOx emissions and increases VOC emissions. This is part of a larger pattern of emissions and economic trade-offs between oxygen content, sulfur content, and olefins content in the gasoline pool.

The least-cost resolution of these trade-offs is influenced by the choice of sulfur control technology. For example, a NOx-limited refinery might favor sulfur control technology that also reduces olefins content. A VOC-limited refinery might favor sulfur control technology that does not reduce olefins content.

California refineries could achieve the sulfur control needed for CaRFG3 production through a combination of FCC feed hydrotreating (pre-treating), sulfur-reducing FCC catalysts, and FCC naphtha hydrotreating (post-treating). "Non-selective" post-treating processes substantially reduce olefins content; "selective" post-treating processes do not.

Because reducing olefins content (all else equal) serves to reduce NOx emissions, use of non-selective post-treating (again, all else equal) tends to favor ethanol blending at 2.7 wt% oxygen over 2.0 wt% oxygen.

For this analysis, we specified a non-selective (i.e., olefin-reducing) post-treating process, for both existing capacity and possible new capacity.

At present, some California refineries practice only severe pre-treating for sulfur control; others practice a combination of conventional pre-treating and post-treating. The two approaches lead to significant differences in FCC naphtha properties. Representing both approaches in one aggregate refining model produces (1) a proliferation of FCC naphtha blendstocks, well beyond the number available in any real refinery, and (2) an apparent capability, unattainable in any real refinery, to tailor the sulfur content of small volumes of special FCC naphtha streams. These two effects can give rise to unrealistic and misleading results.

Consequently, for this analysis, we used separate representations of each sulfur control approach. That is, we configured our California refining model as two parallel models – one representing refineries that practice severe pre-treating; the other representing refineries that practice conventional pre-treating and post-treating. The reported results of the analysis are the volume-weighted sums of the results generated by each model.

3.3 Key Modeling Premises and Assumptions

- The target year for the analysis is 2005.

- The California refining sector has invested as needed to meet the federal Tier 2 sulfur standard for gasoline (produced for sale outside of California) and to meet demand growth.

- The price of Saudi Light crude oil is $25/Bbl (FOB Persian Gulf), and the average acquisition cost of the California crude slate is consistent with that marker crude price.

- The prices of imported gasoline blendstocks (CIF California) are as follows:

-- iso-octane:	$48.80/Bbl
-- alkylate:	$42.35/Bbl
-- C_6 isomerate:	$41.70/Bbl

- Import volumes of these blendstocks are subject to *upper bounds* (corresponding to their estimated availability). That is, import volumes are *not fixed.*

- The prices of ethanol (CIF California, and net of the federal subsidy) are as follows:

-- California-only MTBE ban:	$40-45/Bbl
-- National MTBE ban:	$50-55/Bbl

  These ethanol prices reflect no oxygen waiver outside of California, and continuation of the federal Winter oxygenated gasoline program and all state programs – incentives or mandates – for ethanol blending.

- Gasoline volume lost by the elimination of MTBE is made up by the least-cost combination of ethanol blending, blending of various refinery-produced and merchant-produced blendstocks (e.g., iso-octane/iso-octene, alkylates, and isomerate), and increased crude runs (with accompanying investments in new refining capacity.) That is, the California refining sector meets all product demands without importing finished products or CARBOB.

- Essentially all CaRFG3 is certified with the flat limits variant of the Predictive Model.

- The VOC, NOx, and Toxics emissions targets in the Predictive Model are lower bounds, not fixed targets. Each class (ethanol-blended and non-oxygenated) and grade of CaRFG3 must be certified as complying with the CaRFG3 emission standards.

- Captive MTBE plants can be retro-fitted (and expanded) to produce iso-octane/iso-octene.
- Arizona CBG produced in California refineries is CBG Type 1, corresponding to federal RFG2 but without the oxygen requirement and the limit on toxics emissions.
- The California refining and distribution system has the physical capability to produce and distribute two CaRFG3 pools – one ethanol-blended, the other non-oxygenated – under an oxygen waiver. Volume shares of the two pools are determined by refining economics.
- Under an oxygen waiver, the California refining sector allocates ethanol to both premium and regular gasoline. That is, it does *not* restrict ethanol blending to premium gasoline.
- California refiners have sales outlets for excess C_4 and C_5 streams (rejected for RVP control) and for heavy reformate and heavy FCC naphtha (which could be rejected for aromatics, T_{50}, and T_{90} control).

4. SCENARIOS

4.1 Scenario Definitions

We analyzed the eight (8) scenarios indicated in **Table 1**.

Table 1: Scenarios Analyzed

Descriptors	Scenarios							
	1	2	3	4	5	6	7	8
➢ Oxygen Waiver								
No	X		X		X		X	
Yes		X		X		X		X
➢ MTBE Ban								
National	X	X			X	X		
California			X	X			X	X
➢ Technical Premises								
Set 1	X	X	X	X				
Set 2					X	X	X	X

The symbols (**X**) denote the premises or assumptions represented in the various scenarios. For example, Scenario 1 represents no oxygen waiver, a national MTBE ban, and the first set of technical premises (defined below).

- *Oxygen Waiver* denotes a waiver of the oxygen mandate for federal RFG2 produced in California.

- *MTBE Ban* denotes the geographic scope of a ban on MTBE blending: California-only or nation-wide.

  The assumed scope of an MTBE ban affects only the delivered price of ethanol (CIF California), via our ethanol supply function.

  In turn, the ethanol price influences (1) the relative economics of ethanol blending at 2.0 and 2.7 wt% oxygen and (2) the optimal shares of ethanol-blended and non-oxygenated CaRFG3 in the oxygen waiver scenarios.

- *Technical Premises* denotes two alternative sets of modeling premises used in the analysis.

  -- Set 1: Unocal patents *not* represented in the refinery model;
  Flat limits version of Predictive Model applied to *entire CaRFG3 pool*; and
  "Property deltas" submitted to the Predictive Model are *fixed.*

  -- Set 2: Unocal patents represented in the refinery model;
  Flat limits version of Predictive Model applied to *each grade of CaRFG3*; and
  "Property deltas" submitted to the Predictive Model are *endogenous variables.*

  Set 2 is the more realistic of the two, in terms of capturing the way California refiners comply with the CaRFG program, and incorporates the modifications to the refining model discussed in Section 3. Set 1 represents the way that such compliance has been modeled in prior analyses.

All of the scenarios incorporate the federal RFG2 program and the California CaRFG3 program. All apply to the long term – the time period in which (1) the refining industry and its blendstock suppliers would have completed their investments to deal with an MTBE ban and (2) the new federal standards for low sulfur gasoline (30 ppm average) would be in full effect.

4.2 Estimating Gasoline Pool Shares in the Waiver Scenarios

In each scenario involving an oxygen waiver, we found the cost-minimizing volume shares of ethanol-blended and non-oxygenated gasolines, for ethanol blending at 2.0 wt% oxygen and at 2.7 wt% oxygen. In each such scenario, we analyzed a series of cases. Each case represented a fixed volume ratio of the ethanol-blended and non-oxygenated CaRFG3 pools (e.g., 70%

ethanol-blended/30% non-oxygenated). The cost-minimizing volume share corresponds to the case for which the refining model returns the smallest objective function (adjusted for the cost of ethanol purchases).

All of the results described in Section 5 for the oxygen waiver scenarios apply specifically to the cost-minimizing volume shares found in this manner.

5. RESULTS

5.1 Summary

The principal results of the analysis are tabulated in **Exhibits 1 through 6**.

Exhibit 1 shows – for each of the scenarios defined in Section 4 – the estimated properties of the CaRFG3 pool, with and without an oxygen waiver in place, and the estimated volume shares of ethanol-blended and non-oxygenated CaRFG3, with a waiver in place.

Exhibits 2 through 5 convey a detailed technical description of the refining model's representation of aggregate California refining operations in each scenario.

- Exhibit 2 shows computed capacity utilization, process capacity additions, and key operating indices.
- Exhibit 3 shows refinery charges (crude oil and other feedstocks), energy use, and refined product slates.
- Exhibit 4 shows pool-average gasoline properties, by gasoline type.
- Exhibit 5 shows pool-average gasoline compositions and pool volumes, by gasoline type.

Exhibit 6 summarizes the primary economic results of the analysis: estimated changes in refining costs and investment requirements associated with an oxygen waiver under various scenarios.

5.2 Discussion

5.2.1 Estimated Average Blend Properties and Emissions Reductions

The estimated gasoline properties summarized in Exhibit 1 lead to these findings:

- In all scenarios – that is, for all combinations of ethanol price level and technical premises considered in the analysis – an oxygen waiver would produce a NOx benefit, *as measured by the Beta 3 Predictive Model*.

The NOx benefit arises from "NOx over-compliance" in the non-oxygenated CaRFG3 pool, as a consequence of the relationships between gasoline properties and emissions embodied in the Beta 3 Predictive Model.

- In all scenarios, an oxygen waiver would induce a lower pool-average RVP.

  The advantage in pool-average RVP is small, but significant with respect to the refining model's resolution of RVP.

As is usual in an analysis such as this, we analyzed many exploratory cases in developing the ones covered in this report. Each of the exploratory cases showed a NOx benefit and an RVP reduction flowing from an oxygen waiver, just as the cases in the main scenarios did.

Hence, we judge that the findings of the analysis are robust with respect to the NOx benefit and RVP reduction associated with an oxygen waiver – even though other results (e.g., preferred volume of ethanol blending) are sensitive to technical and economic premises.

5.2.2 Estimated Shares of Ethanol-Blended and Non-Oxygenated CaRFG3 Under a Waiver

The analysis indicates that, under an oxygen waiver:

- The ethanol-blended share of the CaRFG3 pool would be in the range of 25% – 65%, depending mainly on ethanol price and ethanol blending level.
- The ethanol-blended share would likely be somewhat higher if refiners chose ethanol blending at 2.7 wt% oxygen than if they chose blending at 2.0 wt% oxygen.
- The ethanol-blended share would be lower under a national MTBE ban than under a California-only ban, because of the higher ethanol prices induced by a national ban.

5.2.3 Relative Economics of Ethanol Blending at 2.0 and 2.7 wt% Oxygen

The analysis indicates that:

- *Without* an oxygen waiver, ethanol blending would be more attractive at 2.7 wt% oxygen than at 2.0 wt% oxygen for the California refining sector as a whole. The difference in estimated cost between the two is small.
- *With* an oxygen waiver, ethanol blending would be more attractive at 2.7 wt% oxygen – but the cost difference is even smaller than in the no waiver scenarios. In our view, with a waiver, the choice of ethanol concentration (2.7 wt% vs. 2.0 wt% oxygen) is "too close to call" on the basis of economics within the framework of this analysis.

These results correspond explicitly to the premises listed in Section 4. Other premises could lead to different findings.

Discussions with California refiners indicate that some would prefer ethanol blending at 2.0 wt% oxygen, for reasons of refining economics, prospective markets for rejected streams, and/or logistics system limitations. These discussions support the conclusion that – with or without an oxygen waiver – the choice between ethanol blending at 2.7 wt% and 2.0 wt% oxygen would, in practice, turn on a number of technical and economic factors. These factors include:

- Whether or not California refiners would have sales outlets for volumes of C_5 streams (which could be rejected for RVP control) and heavy FCC naphtha and heavy reformate (which could be rejected for aromatics, T_{50}, and T_{90} control).

  Selling some heavy FCC naphtha and/or heavy reformate (either as "neat" streams or blended with rejected pentanes) would tend to tilt the economic balance toward use of the lower ethanol volume.

- The actual extent to which key blendstocks, mostly notably alkylates and ethanol, affect T_{50}.

  The T_{50} effect of alkylate streams is almost stream and blend-specific. It is hard to capture in a refinery-specific LP model, let alone an aggregate model such as we used in this study. A larger T_{50} effect than the one we estimate would favor use of the lower ethanol volume; a smaller T_{50} effect would favor use of the higher ethanol volume.

- The actual CIF price of ethanol and other gasoline blendstocks in California.

  Clearly, the lower the price of ethanol (all else equal), the larger the economic incentive to blend ethanol at the higher volume. Similarly, the lower the price(s) of imported blendstock(s), the smaller the economic incentive to blend ethanol at the higher volume.

5.2.4 Over-Optimization from Aggregate Refinery Modeling

The estimated gasoline pool properties reported in Exhibit 1 probably *understate* the NOx over-compliance discussed in Section 5.2.1, because of a modeling artifact called "over-optimization".

"Over-optimization" denotes the tendency of refinery LP modeling to indicate economic performance – usually higher aggregate profit contributions and/or lower incremental costs of a given refining operation – superior to what one could achieve in practice for a given set of refinery capital stock, product specifications, and market conditions. Over-optimization can occur as the result of various modeling devices. Its extent in a given analysis is hard to quantify.

In this analysis, "over-optimization" produces estimated gasoline pool properties that, in turn, lead to understated emissions benefits from an oxygen waiver. This form of over-optimization arises from two aspects of the modeling approach: representation of aggregate refining capacity and the consequent profusion of gasoline blendstocks represented.

- Aggregate models represent totally coordinated operation of the individual refineries in the specified region or refining aggregate. In this idealized realm, refineries trade intermediate streams and blendstocks freely, making optimal use of all refining capacity, process by process, regardless of the refinery(s) in which the processing capacity resides. Considerable trading of this kind occurs in the refining sector, but in volumes limited by physical and institutional barriers and by the capabilities of the capital stock in place.

- Aggregate models or notional refinery models typically represent more processing options than any one refinery has and, hence, more gasoline blendstocks than any one refinery produces. This profusion of blendstocks gives the refinery model more degrees of freedom in gasoline blending than a real refinery has.

These modeling artifacts lead to computed gasoline blending recipes that lie closer to the blending frontiers defined by specifications and standards – e.g., the Predictive Model emissions targets – than can the gasoline blends produced by real refineries. This phenomenon reduces the reported "give-away" of blending properties and "over-compliance" with emissions standards.

We sought to minimize such over-optimization by reconfiguring our California refining model into two parallel variants, each representing a particular sulfur control regime, as discussed in Section 3.2. This modeling approach dampens "over-optimal" allocation of low-sulfur gasoline blendstocks to particular gasoline pools – with consequent understatement of emissions reductions – which would occur with a single aggregate model. For this reason, the "two-model" approach proved essential to the analysis.

Estimating the extent of over-optimization in a given analysis is difficult and is beyond the scope (budget and temporal) of this project.

5.2.5 Ethanol Use in the Winter Gasoline Season

Los Angeles is the primary California area still in the Winter oxygenated gasoline program. With or without an oxygen waiver for the federal RFG2 program waiver, the Los Angeles area would receive ethanol blended gasoline under the Winter program, at 2.0 or 2.7 wt% oxygen.

In our view, the lower ethanol volume appears the more likely in the Winter. Blending to the higher ethanol volume does not seem to offer economic or emissions benefits. Using the higher ethanol volume offers the refiner no CO emissions credit in the context of the Winter program, because the program deems CO control accomplished by oxygenate blending at any permitted volume. The higher RVP standard in the Winter allows some butane blending. The butane contributes to T_{50} and T_{90} control and delivers some octane-barrels, which permit a reduction in aromatics content. These factors reduce the blending value of incremental ethanol volumes in the Winter.

Areas of California – e.g., San Diego and Sacramento – that are in the federal RFG2 program but not the Winter oxygenated gasoline program could receive non-oxygenated or ethanol-blended CaRFG3 in the Winter. Consideration of refining economics suggests that the non-oxygenated share would likely be higher in the Winter than in the Summer. However, practical considerations in the gasoline distribution system could alter this outlook and determine the extent of ethanol blending in the Winter.

The same considerations would apply to those areas of California that are in neither the federal RFG2 program or the Winter oxygenated gasoline program.

6. REFERENCES

1. *Analysis of the Refining Economics of California Phase 3 Gasoline,* MathPro Inc., prepared for the California Energy Commission, January 5, 2000.

2. *Analysis of Alternative California Phase 3 RFG Standards,* MathPro Inc., prepared for the Western States Petroleum Association, December 7, 1999

3. *Potential Economic Benefits of the Feinstein-Bilbray Bill*, MathPro Inc., prepared for Chevron Products Company and Tosco Corporation, March 18, 1999

4. *Evaluating the Cost and Supply of Alternatives to MTBE in California's Reformulated Gasoline,* Task 3: Supply Scenario Modeling Runs, MathPro Inc., prepared for the California Energy Commission, December 9, 1998.

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, Grade by Grade Flat Limits, Variable Property Deltas					
	California Only MTBE Ban*			National MTBE Ban**			California Only MTBE Ban*			National MTBE Ban**		
	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.

Exhibit 2: Process Unit Utilization, Additions, and Operations

(K bbl/d)

		Model Formulation: No Unocal Patent, Pool Flat Limits, Fixed Property Deltas					
		Wt% Oxygen in Oxygenated Gasoline					
		2.0 Percent			2.7 Percent		
			Waiver			Waiver	
Type of Process	**Process**	**No Waiver**	**Calif. Ban**	**Nat'l Ban**	**No Waiver**	**Calif. Ban**	**Nat'l Ban**
USE OF EXISTING CAP.							
Crude Distillation	Atmospheric	1975	1960	1987	1996	1988	1994
Conversion	Fluid Cat Cracker	732	732	732	732	732	732
	Hydrocracker - Distillate Feed	291	291	291	291	291	291
	Hydrocracker - Gas Oil Feed	120	115	124	127	125	128
	Coking - Delayed	342	354	351	336	354	355
	Coking - Fluid & Flexi	106	106	106	106	106	106
Upgrading	Alkylation	176	175	162	177	177	175
	Dimersol			2			
	Pen/Hex Isom. (Once Thru)	53	75	82	63	76	76
	Pen/Hex Isom. (Recycle)						
	Polymerization						
	Reforming (150-350 psi)	387	403	418	367	405	418
Oxygenate Prod.	MTBE Plant -- Captive						
	Tame Plant						
Hydrotreating	Naphtha & Isom Feed Desulf.	68	74	75	106	78	79
	Reformer Feed Desulfurization	306	314	314	268	308	318
	Distillate Desulfurization	365	359	385	382	369	388
	Distillate Dearomatization	149	157	154	148	152	136
	FCC Feed Desulf. -- Conv.	349	351	351	349	351	351
	FCC Feed Desulf. -- Deep	377	377	377	377	377	377
	FCC Naphtha Desulf. (Non-Selective)	30	30	30	30	30	30
	Benzene Saturation	58	66	66	64	66	66
Hydrogen (MM scf/d)	Hydrogen Plant	1294	1302	1308	1308	1308	1308
Other	Aromatics Plant						
	Butane Isomerization	18	18	9	18	18	16
	Lubes & Waxes	25	25	25	25	25	25
	Merox Treatment of MTBE/IsoOctene						
	Solvent Deasphalting	50	50	50	50	50	50
	Sulfur Recovery (tons/d)	6557	6595	6606	6556	6611	6619
Fractionation	Debutanization	189	189	192	190	191	192
	Depentanization	113	113	113	113	113	113
	Lt. Naphtha Spl. (Benz. Prec.)	153	153	153	153	153	153
	Naphtha Splitter (T90 Control)	24	70	70	3	38	70
	FCC Naphtha Splitter	298	327	339	338	314	289
	FCC Naphtha T90 Control	56	54	54	57	56	56
RETROFIT CAPACITY							
IsoOctane/Octene*	From Captive MTBE	4	4	7	4	4	4
NEW CAPACITY							
Crude Distillation	Atmospheric						
Upgrading	Alkylation	38	19	20	29	21	23
	IsoOctane/ene	8	7	5	7	4	
Hydrotreating	Naphtha Desulfurization						
	FCC Naphtha Desulf. (Non-Selective)	85	107	108	110	115	116
	Benzene Saturation		6	14		0	9
Hydrogen (foeb)	Hydrogen Plant (MM scf/d)	43	70	121	71	80	96
Other	Benzene Extraction						
	FCC Gas Processing	178	95	111	116	77	56
	Merox Treatment of MTBE	12	11	12	11	8	4
	Butane Isomerization						
	Sulfur Recovery (tons/d)						
Fractionation	Alkylate Fractionation (Lt. Alkylate)						
	Debutanization	169	73	100	19	19	19
	Depentanization	105	46	14	225	136	92
	Lt. Naphtha Spl. (Benz. Prec.)	30	49	50	6	51	51
	Naphtha Splitter (T90 Control)		4	62			35
	FCC Naphtha Splitter	2	15	18	9	18	25
	FCC Naphtha (T90 Control)	10	9	25	24	6	2
OPERATIONS							
Operating Indices	FCC Conversion (Vol %)	69	69	69	70	70	70
	Reformer Severity (RON)	100	100	100	100	100	100
Charge Rates	Fluid Cat Cracker	730	732	732	730	732	732
	Reformer (150-350 psi)	387	403	418	367	405	418
FCC Olefin Max Cat. (%)		22	12	14	15	10	7

Exhibit 2: Process Unit Utilization, Additions, and Operations
(K bbl/d)

		Model Formulation: Unocal Patent, Grade-by-Grade Flat Limits, Variable Property Deltas					
		Wt% Oxygen in Oxygenated Gasoline					
		2.0 Percent			2.7 Percent		
			Waiver			Waiver	
Type of Process	Process	No Waiver	Calif. Ban	Nat'l Ban	No Waiver	Calif. Ban	Nat'l Ban
USE OF EXISTING CAP.							
Crude Distillation	Atmospheric	1969	1984	1973	1988	1987	2002
Conversion	Fluid Cat Cracker	732	732	732	729	727	732
	Hydrocracker - Distillate Feed	291	291	291	291	291	291
	Hydrocracker - Gas Oil Feed	117	123	123	129	130	130
	Coking - Delayed	330	351	368	344	354	352
	Coking - Fluid & Flexi	106	106	106	106	106	106
Upgrading	Alkylation	171	163	162	178	167	164
	Dimersol			2			
	Pen/Hex Isom. (Once Thru)	61	76	76	62	76	76
	Pen/Hex Isom. (Recycle)						
	Polymerization			1			
	Reforming (150-350 psi)	378	411	418	367	394	410
Oxygenate Prod.	MTBE Plant -- Captive						
	Tame Plant						
Hydrotreating	Naphtha & Isom Feed Desulf.	59	79	75	99	80	79
	Reformer Feed Desulfurization	292	325	317	274	299	321
	Distillate Desulfurization	374	385	384	386	391	390
	Distillate Dearomatization	163	138	155	147	149	140
	FCC Feed Desulf. -- Conv.	347	351	350	349	351	351
	FCC Feed Desulf. -- Deep	377	377	377	374	372	377
	FCC Naphtha Desulf. (Non-Selective)	30	30	30	30	30	30
	Benzene Saturation	62	66	66	60	66	66
Hydrogen (MM scf/d)	Hydrogen Plant	1308	1308	1308	1308	1308	1308
Other	Aromatics Plant						
	Butane Isomerization	15	9	9	18	12	9
	Lubes & Waxes	25	25	25	25	25	25
	Merox Treatment of MTBE/IsoOctene						
	Solvent Deasphalting	50	50	50	50	50	50
	Sulfur Recovery (tons/d)	6511	6605	6645	6559	6591	6619
Fractionation	Debutanization	188	190	192	190	190	192
	Depentanization	113	113	113	113	113	113
	Lt. Naphtha Spl. (Benz. Prec.)	153	153	153	153	153	153
	Naphtha Splitter (T90 Control)	13	67	70	3	35	62
	FCC Naphtha Splitter	339	339	339	339	339	339
	FCC Naphtha T90 Control	57	57	57	57	57	57
RETROFIT CAPACITY							
IsoOctane/Octene*	From Captive MTBE	8	8	8	4	8	8
NEW CAPACITY							
Crude Distillation	Atmospheric		1				1
Upgrading	Alkylation	29	22	21	29	23	23
	IsoOctane/ene	7	10	12	6	4	8
Hydrotreating	Naphtha Desulfurization						
	FCC Naphtha Desulf. (Non-Selective)	105	117	118	117	114	119
	Benzene Saturation		6	21			5
Hydrogen (foeb)	Hydrogen Plant (MM scf/d)	61	96	142	71	106	131
Other	Benzene Extraction						
	FCC Gas Processing	128	91	140	120	73	91
	Merox Treatment of MTBE	15	19	21	10	12	17
	Butane Isomerization						
	Sulfur Recovery (tons/d)						
Fractionation	Alkylate Fractionation (Lt. Alkylate)			60		8	10
	Debutanization	20	21	18	19	20	20
	Depentanization	243	173	80	208	162	85
	Lt. Naphtha Spl. (Benz. Prec.)	38	50	53	13	44	43
	Naphtha Splitter (T90 Control)		12	41			35
	FCC Naphtha Splitter	14	21	26	14	21	31
	FCC Naphtha (T90 Control)	33	6	11	20	22	14
OPERATIONS							
Operating Indices	FCC Conversion (Vol %)	70	70	70	70	70	70
	Reformer Severity (RON)	100	100	100	100	100	100
Charge Rates	Fluid Cat Cracker	728	732	730	727	727	732
	Reformer (150-350 psi)	378	411	418	367	394	410
FCC Olefin Max Cat. (%)		16	11	18	15	9	11

Exhibit 3: Crude Oil, Other Inputs, and Refined Product Outputs

(K barrels/day)

	Model Formulation: No Unocal Patent, Pool Flat Limits, Fixed Property Deltas					
	Wt% Oxygen in Oxygenated Gasoline					
	2.0 Percent			2.7 Percent		
		Waiver			Waiver	
Inputs/ Outputs	No Waiver	Calif. Ban	Nat'l Ban	No Waiver	Calif. Ban	Nat'l Ban
Crude Oil						
Composite	1,975	1,960	1,987	1,996	1,987	1,994
Other Inputs						
Isobutane	15			6		
Butane						
Natural Gas Liquids						
C6 Isomerate	97	82	70	49	68	69
Full Range Alkylate	14	43	52	33	31	31
IsoOctane	33	33	33	12	18	28
Reformate						
Heavy Gas Oil	19	19	19	19	19	19
Residual Oil	38	38	38	38	38	38
MTBE						
Ethanol	59	30	21	79	48	33
Methanol						
Energy Use						
Electricity (K Kwh)	19,666	19,747	20,471	19,548	19,885	20,302
Fuel (foeb)	243	246	253	244	248	251
Refined Product Out-turns						
BTX						
Propane	37	37	37	37	37	37
Propylene	7	7	7	7	7	7
Butane						
Mixed Butylenes	4	4	4	4	4	4
Naphtha	3	3	3	3	3	3
Gasoline:						
Calif. RFG3 (Oxy)	1,022	526	374	1,022	622	426
Calif. RFG3 (No Oxy)		496	648		400	596
Arizona CBG	68			68		
Conventional	161			161		
Arizona CBG & Conv.		229	229		229	229
Aviation Gasoline	5	5	5	5	5	5
Jet Fuel	333	333	333	333	333	333
CARB Diesel	204	204	204	204	204	204
On-road Diesel (< 0.05% Sulf)	122	122	122	122	122	122
Other Diesel/Heating Oil	18	18	18	18	18	18
Carbon Black Feed						
Residual Oil	98	79	92	108	84	86
Asphalt						
Lubes & Waxes	25	25	25	25	25	25
Coke	130	134	133	128	134	134
Sulfur (k tons/d)	7	7	7	7	7	7
Rejected Blendstocks	28			7		

Exhibit 3: Crude Oil, Other Inputs, and Refined Product Outputs

(K barrels/day)

	Model Formulation: Unocal Patent, Grade-by-Grade Flat Limits, Variable Property Deltas					
	Wt% Oxygen in Oxygenated Gasoline					
	2.0 Percent			2.7 Percent		
		Waiver			Waiver	
Inputs/ Outputs	No Waiver	Calif. Ban	Nat'l Ban	No Waiver	Calif. Ban	Nat'l Ban
Crude Oil						
Composite	1,968	1,984	1,973	1,988	1,987	2,002
Other Inputs						
Isobutane	6			6		
Butane						
Natural Gas Liquids						
C6 Isomerate	82	84	79	47	51	61
Full Range Alkylate	52	36	46	34	53	47
IsoOctane	19	28	30	12	12	15
Reformate						
Heavy Gas Oil	19	19	19	19	19	19
Residual Oil	38	38	38	38	38	38
MTBE						
Ethanol	59	30	16	79	52	37
Methanol						
Energy Use						
Electricity (K Kwh)	19,475	20,153	20,540	19,609	19,991	20,430
Fuel (foeb)	242	250	254	244	248	253
Refined Product Out-turns						
BTX						
Propane	37	37	37	37	37	37
Propylene	7	7	7	7	7	7
Butane						
Mixed Butylenes	4	4	4	4	4	4
Naphtha	3	3	3	3	3	3
Gasoline:						
Calif. RFG3 (Oxy)	1,022	526	271	1,022	674	478
Calif. RFG3 (No Oxy)		496	751		348	544
Arizona CBG	68			68		
Conventional	161			161		
Arizona CBG & Conv.		229	229		229	229
Aviation Gasoline	5	5	5	5	5	5
Jet Fuel	333	333	333	333	333	333
CARB Diesel	204	204	204	204	204	204
On-road Diesel (< 0.05% Sulf)	122	122	122	122	122	122
Other Diesel/Heating Oil	18	18	18	18	18	18
Carbon Black Feed						
Residual Oil	101	88	65	95	85	92
Asphalt						
Lubes & Waxes	25	25	25	25	25	25
Coke	126	133	139	131	134	133
Sulfur (k tons/d)	7	7	7	7	7	7
Rejected Blendstocks	21			8		

Exhibit 4: Gasoline Properties, by Case and Gasoline Type

	Model Formulation: No Unocal Patent, Pool Flat Limits, Fixed Property Deltas											
	2.0 wt% Oxygen &											
					Waiver							
Property &	No Waiver				California Ban				National Ban			
	CARB				CARB		Ariz &		CARB		Ariz &	
Volume	Oxy	Ariz	Conv.	Pool	Oxy	No Oxy	Conv.	Pool	Oxy	No Oxy	Conv.	Pool
Property												
RVP (psi)*	6.66	6.60	7.70	6.79	6.60	6.60	7.37	6.74	6.60	6.60	7.37	6.74
Oxygen (wt%)	2.0	0.0	0.0	1.6	2.0	0.0	0.0	0.8	2.0	0.0	0.0	0.6
Aromatics (vol%)	24.1	18.8	34.4	25.2	26.5	23.0	30.4	25.9	19.2	28.6	30.4	26.1
Benzene (vol%)	0.64	0.76	0.76	0.67	0.62	0.57	0.71	0.62	0.77	0.51	0.80	0.64
Olefins (vol%)	4.4	8.7	6.1	4.9	3.4	5.9	5.7	4.8	4.6	4.7	8.1	5.3
Sulfur (ppm)	14	25	25	16	17	8	19	14	17	7	17	12
E200 (vol% off)	47.2	40.2	38.9	45.7	46.8	47.7	39.2	45.7	45.2	48.7	39.2	45.9
E300 (vol% off)	87.6	83.4	76.4	86.0	88.3	87.4	79.0	86.2	90.6	87.6	79.0	86.9
T10**	137	129	125	135	137	137	129	136	136	139	128	136
T50**	208	215	226	210	209	206	221	210	213	203	222	210
T90**	307	331	348	313	305	307	339	312	298	307	333	309
Estimated DI***	1,174	1,170	1,213	1,179	1,176	1,132	1,196	1,163	1,180	1,125	1,193	1,154
En. Den. (MM Btu/bbl)	5.133	5.213	5.252	5.153	5.139	5.188	5.234	5.176	5.131	5.194	5.229	5.181
Volume (K bbl/d)	1,022	68	161	1,251	526	496	229	1,251	374	648	229	1,251

* Final blended RVP.

** Linear interpolations from ARMS generated distillation curves for T10 and T50 & T90 for Arizona CBG and Conventional Gasoline.; T50 = (125.3846 - E200)/0.3769 and T90 = (196.1538 - E300)/0.3538 for California RFG

*** Calculated as follows: 1.5*T10 + 3.0*T50 + 1.0*T90 + 20*(wt% oxygen from ethanol).

Note: Emissions calculations based on: Phase II Complex Model for Arizona gasoline; Phase 2 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG2; and Phase 3 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG3.

Exhibit 4: Gasoline Properties, by Case and Gasoline Type

	Model Formulation: No Unocal Patent, Pool Flat Limits, Fixed Property Deltas											
	2.7 wt% Oxygen &											
					Waiver							
Property &	No Waiver				California Ban				National Ban			
	CARB				CARB		Ariz &		CARB		Ariz &	
Volume	Oxy	Ariz	Conv.	Pool	Oxy	No Oxy	Conv.	Pool	Oxy	No Oxy	Conv.	Pool
Property												
RVP (psi)*	6.85	6.64	7.70	6.95	6.76	6.60	7.37	6.82	6.60	6.60	7.37	6.74
Oxygen (wt%)	2.7	0.0	0.0	2.2	2.7	0.0	0.0	1.3	2.7	0.0	0.0	0.9
Aromatics (vol%)	23.2	18.3	34.4	24.4	25.7	24.8	30.3	26.3	22.4	28.6	30.3	26.8
Benzene (vol%)	0.69	0.80	0.71	0.70	0.66	0.52	0.80	0.64	0.71	0.53	0.80	0.64
Olefins (vol%)	3.8	10.0	6.3	4.4	2.8	6.1	6.1	4.4	2.8	4.0	7.7	4.3
Sulfur (ppm)	9	25	25	12	10	12	25	13	12	10	20	13
E200 (vol% off)	46.9	40.0	38.9	45.5	46.1	49.1	39.3	45.8	44.9	49.2	39.3	45.9
E300 (vol% off)	88.1	83.5	76.4	86.4	88.6	85.8	78.8	85.9	87.7	87.4	78.8	85.9
T10**	136	129	124	134	136	139	127	135	135	139	127	136
T50**	208	213	225	211	210	202	221	210	214	202	221	210
T90**	305	328	348	312	304	312	343	314	307	307	339	313
Estimated DI***	1,189	1,160	1,208	1,190	1,193	1,127	1,196	1,173	1,205	1,122	1,194	1,164
En. Den. (MM Btu/bbl)	5.098	5.205	5.244	5.123	5.103	5.199	5.241	5.159	5.090	5.213	5.241	5.176
Volume (K bbl/d)	1,022	68	161	1,251	622	400	229	1,251	426	596	229	1,251

* Final blended RVP.

** Linear interpolations from ARMS generated distillation curves for T10 and T50 & T90 for Arizona CBG and Conventional Gasoline.;
T50 = (125.3846 - E200)/0.3769 and T90 = (196.1538 - E300)/0.3538 for California RFG

*** Calculated as follows: 1.5*T10 + 3.0*T50 + 1.0*T90 + 20*(wt% oxygen from ethanol).

Note: Emissions calculations based on: Phase II Complex Model for Arizona gasoline; Phase 2 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG2; and Phase 3 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG3.

Exhibit 4: Gasoline Properties, by Case and Gasoline Type

	Model Formulation: Unocal Patent, Grade-by-Grade Flat Limits, Variable Property Deltas											
	2.0 wt% Oxygen &											
					Waiver							
Property &	No Waiver				California Ban				National Ban			
	CARB				CARB		Ariz &		CARB		Ariz &	
Volume	Oxy	Ariz	Conv.	Pool	Oxy	No Oxy	Conv.	Pool	Oxy	No Oxy	Conv.	Pool
Property												
RVP (psi)*	6.74	6.63	7.70	6.86	6.62	6.60	7.39	6.75	6.60	6.60	7.39	6.74
Oxygen (wt%)	2.0	0.0	0.0	1.6	2.0	0.0	0.0	0.8	2.0	0.0	0.0	0.4
Aromatics (vol%)	23.3	19.3	34.4	24.5	24.3	26.9	29.9	26.4	28.6	24.3	29.9	26.3
Benzene (vol%)	0.57	0.77	0.80	0.61	0.60	0.46	0.76	0.57	0.51	0.49	0.80	0.55
Olefins (vol%)	3.9	9.4	6.3	4.5	3.7	2.4	6.6	3.7	2.9	3.9	6.1	4.1
Sulfur (ppm)	10	18	25	12	12	8	19	12	12	10	20	12
E200 (vol% off)	46.4	40.0	38.9	45.1	46.2	48.1	39.2	45.7	46.1	47.6	39.2	45.8
E300 (vol% off)	88.7	84.2	76.4	86.9	87.7	87.2	78.8	85.9	88.2	88.1	78.8	86.4
T10**	136	129	124	134	137	139	126	136	138	138	128	136
T50**	210	213	226	212	210	205	222	210	210	206	221	210
T90**	304	327	349	311	307	308	343	314	305	306	340	312
Estimated DI***	1,177	1,159	1,212	1,180	1,182	1,132	1,198	1,165	1,184	1,132	1,195	1,155
En. Den. (MM Btu/bbl)	5.124	5.218	5.251	5.145	5.147	5.188	5.239	5.180	5.148	5.195	5.237	5.192
Volume (K bbl/d)	1,022	68	161	1,251	526	496	229	1,251	271	751	229	1,251

* Final blended RVP.

** Linear interpolations from ARMS generated distillation curves for T10 and T50 & T90 for Arizona CBG and Conventional Gasoline.;
T50 = (125.3846 - E200)/0.3769 and T90 = (196.1538 - E300)/0.3538 for California RFG

*** Calculated as follows: 1.5*T10 + 3.0*T50 + 1.0*T90 + 20*(wt% oxygen from ethanol).

Note: Emissions calculations based on: Phase II Complex Model for Arizona gasoline; Phase 2 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG2; and Phase 3 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG3.

Exhibit 4: Gasoline Properties, by Case and Gasoline Type

Property & Volume	Model Formulation: Unocal Patent, Grade-by-Grade Flat Limits, Variable Property Deltas											
	2.7 wt% Oxygen &											
					Waiver							
	No Waiver				California Ban				National Ban			
	CARB				CARB		Ariz &		CARB		Ariz &	
	Oxy	Ariz	Conv.	Pool	Oxy	No Oxy	Conv.	Pool	Oxy	No Oxy	Conv.	Pool
Property												
RVP (psi)*	6.84	6.60	7.70	6.94	6.73	6.60	7.37	6.81	6.69	6.60	7.37	6.77
Oxygen (wt%)	2.7	0.0	0.0	2.2	2.7	0.0	0.0	1.5	2.7	0.0	0.0	1.0
Aromatics (vol%)	23.2	20.0	34.4	24.5	26.3	21.2	29.8	25.5	25.4	25.7	29.8	26.3
Benzene (vol%)	0.68	0.79	0.70	0.69	0.63	0.52	0.71	0.61	0.65	0.49	0.77	0.60
Olefins (vol%)	3.8	9.7	6.3	4.4	1.9	6.3	6.2	3.9	2.8	3.9	6.3	3.9
Sulfur (ppm)	9	18	25	12	8	12	23	12	10	9	20	11
E200 (vol% off)	46.6	40.0	38.9	45.3	45.4	47.6	39.2	44.9	45.4	47.9	39.2	45.4
E300 (vol% off)	88.0	84.0	76.4	86.3	89.0	86.8	78.5	86.5	88.3	87.6	78.5	86.2
T10**	136	129	124	134	137	138	126	135	136	139	128	136
T50**	209	213	224	211	212	206	221	212	212	205	222	211
T90**	306	328	348	312	303	309	344	312	305	307	341	312
Estimated DI***	1,191	1,160	1,206	1,191	1,199	1,135	1,196	1,181	1,201	1,131	1,197	1,170
En. Den. (MM Btu/bbl)	5.099	5.221	5.242	5.124	5.111	5.182	5.234	5.153	5.110	5.198	5.237	5.171
Volume (K bbl/d)	1,022	68	161	1,251	674	348	229	1,251	478	544	229	1,251

* Final blended RVP.

** Linear interpolations from ARMS generated distillation curves for T10 and T50 & T90 for Arizona CBG and Conventional Gasoline.;
T50 = (125.3846 - E200)/0.3769 and T90 = (196.1538 - E300)/0.3538 for California RFG

*** Calculated as follows: 1.5*T10 + 3.0*T50 + 1.0*T90 + 20*(wt% oxygen from ethanol).

Note: Emissions calculations based on: Phase II Complex Model for Arizona gasoline; Phase 2 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG2; and Phase 3 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG3.

Exhibit 5: Gasoline Composition and Volume, by Gasoline Type

	Model Formulation: No Unocal Patent, Pool Flat Limits, Fixed Property Deltas											
	2.0 wt% Oxygen &											
	No Waiver				Waiver							
					California Ban				National Ban			
Composition & Volume	CARB Oxy	Ariz	Conv.	Pool	CARB Oxy	CARB No Oxy	Ariz & Conv.	Pool	CARB Oxy	CARB No Oxy	Ariz & Conv.	Pool
Composition (vol%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C4s:	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5
Butenes												
I-Butane											0.3	0.0
N-Butane	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.5
C5s & Isomerate	14.5		8.5	12.9	11.9	18.6	4.6	13.2	7.7	18.8	9.5	13.8
Raffinate												
Natural Gas Liquids												
Naphtha	3.6		3.9	3.4		4.7	3.4	2.5		2.6	3.6	2.0
C5-160	2.2		2.4	2.1		4.7	3.4	2.5		2.6	3.6	2.0
Coker Naphtha												
160-250	1.3		1.5	1.3								
Alkylate	20.2	34.5	20.1	21.0	17.7	24.9	24.6	21.8	23.6	20.6	18.1	21.1
Hydrocrackate	6.8	13.6	16.9	8.5	9.1	2.2	18.1	8.0	11.8	5.1	14.0	8.7
Poly Gasoline										0.4		0.2
FCC Gasoline:	25.6	36.3	10.1	24.2	31.8	23.6	15.8	25.6	36.4	19.3	22.8	25.1
Full Range	3.4	14.3		3.6	4.2			1.8			3.2	0.6
Full Range - Desulf.												
Light	3.5	13.7		3.6	1.3	9.2	3.2	4.8	5.5	4.6	4.6	4.9
Light - Desulf.												
Medium	8.5	4.8		7.2	13.3	5.0	0.7	7.7	19.0	3.3	4.5	8.2
Medum - Desulf.	5.9			4.8	8.2	5.3		5.5	10.3	4.9		5.6
Heavy	1.5	2.0	7.9	2.3	1.2	1.7	7.7	2.6		3.0	4.9	2.5
Heavy - Desulf.	2.8	1.5	2.2	2.7	3.7	2.5	4.1	3.3	1.6	3.4	5.6	3.3
Reformate	23.0	15.2	40.1	24.8	23.2	25.4	33.1	25.9	14.3	32.7	31.4	26.9
Light	11.6		7.9	10.5	16.8	10.2	8.2	12.6	4.8	22.0	2.6	13.3
Medium		1.4	7.1	1.0			17.0	3.1	0.4		28.2	5.3
Heavy	11.4	13.8	25.1	13.3	6.5	15.2	7.9	10.2	9.1	10.6	0.6	8.3
Oxygenate	5.7			4.7	5.7			2.4	5.7			1.7
MTBE												
TAME												
Ethanol	5.7			4.7	5.7			2.4	5.7			1.7
Gasoline Volume (K Bbl/day)	1,022	68	161	1,251	526	496	229	1,251	374	648	229	1,251

Exhibit 5: Gasoline Composition and Volume, by Gasoline Type

	Model Formulation:											
	No Unocal Patent, Pool Flat Limits, Fixed Property Deltas											
	2.7 wt% Oxygen &											
					Waiver							
	No Waiver				California Ban				National Ban			
Composition &	**CARB**				**CARB**		**Ariz &**		**CARB**		**Ariz &**	
Volume	**Oxy**	**Ariz**	**Conv.**	**Pool**	**Oxy**	**No Oxy**	**Conv.**	**Pool**	**Oxy**	**No Oxy**	**Conv.**	**Pool**
Composition (vol%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C4s:	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5
Butenes												
I-Butane												
N-Butane	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5
C5s & Isomerate	10.8		8.5	9.9	14.1	13.5	4.7	12.2	17.6	11.6	4.8	12.4
Raffinate												
Natural Gas Liquids												
Naphtha	6.0		3.8	5.4	1.0	5.2	1.8	2.5		4.6	1.7	2.5
C5-160	2.6		2.4	2.4	1.0	5.2	1.7	2.5		4.6	1.7	2.5
Coker Naphtha							0.2	0.0				
160-250	3.4		1.5	3.0								
Alkylate	19.8	31.2	20.9	20.5	13.3	28.2	23.7	20.0	17.7	21.7	20.8	20.2
Hydrocrackate	8.7	8.9	16.5	9.7	11.2	1.2	19.1	9.4	9.9	5.2	15.8	8.7
Poly Gasoline												
FCC Gasoline:	24.2	48.8	12.9	24.1	26.9	27.4	18.3	25.5	24.8	27.0	26.3	26.1
Full Range	2.9	7.3	0.1	2.8	1.4	3.9	7.0	3.2	1.2	5.2	11.4	5.0
Full Range - Desulf.												
Light	3.7	18.0	0.1	4.0	1.5	9.3	3.2	4.3	1.3	5.8	6.3	4.4
Light - Desulf.												
Medium	8.5	16.0		7.9	11.1	4.0		6.8	15.3	1.2		5.8
Medum - Desulf.	7.4			6.0	12.2			6.1	6.9	7.8		6.1
Heavy	1.6	2.4	10.3	2.8	0.7	4.0	4.9	2.5		3.0	3.1	2.0
Heavy - Desulf.	0.0	5.0	2.3	0.6		6.3	3.2	2.6		4.1	5.5	2.9
Reformate	22.3	10.6	36.9	23.5	25.2	24.0	31.9	26.1	21.8	29.4	30.1	26.9
Light	10.0	0.0	12.5	9.7	9.3	21.2	5.6	12.4	2.7	24.3	3.0	13.1
Medium		0.8	0.5	0.1			8.6	1.6			23.3	4.3
Heavy	12.3	9.8	23.9	13.7	15.9	2.8	17.7	12.1	19.1	5.1	3.8	9.6
Oxygenate	7.8			6.3	7.8			3.9	7.8			2.6
MTBE												
TAME												
Ethanol	7.8			6.3	7.8			3.9	7.8			2.6
Gasoline Volume (K Bbl/day)	1,022	68	161	1,251	622	400	229	1,251	426	596	229	1,251

Exhibit 5: Gasoline Composition and Volume, by Gasoline Type

Composition & Volume	Model Formulation: Unocal Patent, Grade-by-Grade Flat Limits, Variable Property Deltas 2.0 wt% Oxygen &											
	No Waiver				Waiver							
					California Ban				National Ban			
	CARB				CARB		Ariz &		CARB		Ariz &	
	Oxy	Ariz	Conv.	Pool	Oxy	No Oxy	Conv.	Pool	Oxy	No Oxy	Conv.	Pool
Composition (vol%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C4s:	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	1.0	0.8
Butenes												
I-Butane										0.1	0.2	0.1
N-Butane	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7
C5s & Isomerate	13.8		8.5	12.4	11.4	19.8	4.4	13.4	22.2	12.3	2.6	12.7
Raffinate												
Natural Gas Liquids												
Naphtha	2.0		3.8	2.2		5.4	1.7	2.5		3.2	3.2	2.5
C5-160	1.8		2.4	1.7		5.4	1.7	2.5		3.2	3.2	2.5
Coker Naphtha												
160-250	0.3		1.5	0.4								
Alkylate	22.2	31.0	20.2	22.4	18.9	21.7	25.1	21.2	12.2	24.2	24.9	21.7
Hydrocrackate	8.4	11.6	17.5	9.8	7.9	4.8	18.0	8.5	1.1	8.5	17.6	8.5
Poly Gasoline										0.5		0.3
FCC Gasoline:	24.7	42.0	10.9	23.8	34.6	17.3	20.0	25.1	26.2	25.7	22.6	25.2
Full Range												
Full Range - Desulf.												
Light	3.9	20.0	0.1	4.3	4.8	3.5	5.7	4.5	2.5	5.7	5.8	5.0
Light - Desulf.										0.1		0.1
Medium	8.6	14.8	0.8	7.9	16.0	1.7	2.9	7.9	20.0	4.3	2.8	7.4
Medum - Desulf.	7.5			6.1	9.1	6.0		6.2	1.8	10.1		6.5
Heavy	2.1	5.2	7.7	3.0	1.5	3.4	6.9	3.2	1.9	3.2	5.3	3.3
Heavy - Desulf.	2.6	1.9	2.3	2.6	3.2	2.8	4.5	3.2		2.3	8.7	2.9
Reformate	22.6	15.0	38.6	24.3	20.9	30.4	30.4	26.4	32.1	24.7	28.0	26.9
Light	12.5	0.6	7.5	11.2	8.9	18.3	6.3	12.2	14.3	13.5	10.8	13.2
Medium	0.2	0.8	2.6	0.6	3.3		10.2	3.2	4.9	5.1	2.2	4.5
Heavy	9.9	13.6	28.5	12.5	8.7	12.1	14.0	11.0	12.8	6.2	15.0	9.2
Oxygenate	5.7			4.7	5.7			2.4	5.7			1.2
MTBE												
TAME												
Ethanol	5.7			4.7	5.7			2.4	5.7			1.2
Gasoline Volume (K Bbl/day)	1,022	68	161	1,251	526	496	229	1,251	271	751	229	1,251

Exhibit 5: Gasoline Composition and Volume, by Gasoline Type

Composition & Volume	Model Formulation: Unocal Patent, Grade-by-Grade Flat Limits, Variable Property Deltas											
	2.7 wt% Oxygen &											
					Waiver							
	No Waiver				California Ban				National Ban			
	CARB				CARB		Ariz &		CARB		Ariz &	
	Oxy	Ariz	Conv.	Pool	Oxy	No Oxy	Conv.	Pool	Oxy	No Oxy	Conv.	Pool
Composition (vol%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C4s:	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Butenes												
I-Butane											0.0	0.0
N-Butane	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6
C5s & Isomerate	10.6		8.6	9.7	10.9	14.8	5.2	10.9	12.0	14.4	2.6	11.3
Raffinate												
Natural Gas Liquids												
Naphtha	5.5		3.8	5.0	2.2	3.8	2.7	2.7	1.2	3.9	1.7	2.5
C5-160	2.6		2.4	2.5	2.1	3.8	1.7	2.5	1.2	3.9	1.7	2.5
Coker Naphtha												
160-250	2.9		1.5	2.5	0.1		1.0	0.3				
Alkylate	19.9	29.6	20.6	20.5	15.4	28.4	26.1	21.0	17.0	21.8	25.2	20.6
Hydrocrackate	9.3	11.1	15.7	10.2	12.4	2.5	18.1	10.7	11.9	4.8	18.8	10.1
Poly Gasoline												
FCC Gasoline:	24.5	42.6	14.5	24.2	24.1	30.2	17.4	24.6	24.9	27.5	22.3	25.5
Full Range												
Full Range - Desulf.												
Light	3.8	14.9		3.9	1.7	10.6	3.7	4.5	2.8	5.7	7.0	4.8
Light - Desulf.												
Medium	8.5	22.6	0.5	8.3	9.5	14.8	1.0	9.4	12.3	9.7	1.2	9.1
Medum - Desulf.	7.5			6.1	10.9	1.4		6.3	5.9	9.1		6.2
Heavy	1.3	5.1	10.2	2.6	0.8	3.4	8.9	3.0		2.9	8.8	2.9
Heavy - Desulf.	3.4		3.7	3.2	1.3		3.8	1.4	3.9		5.3	2.5
Reformate	22.0	16.2	36.3	23.5	26.7	19.7	30.0	25.4	24.7	27.0	28.8	26.4
Light	9.6	0.5	14.5	9.7	11.4	14.7	8.8	11.8	11.4	15.0	6.5	12.1
Medium		1.0	0.3	0.1			8.0	1.5		0.7	19.9	3.9
Heavy	12.4	14.6	21.5	13.7	15.3	5.0	13.3	12.1	13.3	11.3	2.4	10.4
Oxygenate	7.8			6.3	7.8			4.2	7.8			3.0
MTBE												
TAME												
Ethanol	7.8			6.3	7.8			4.2	7.8			3.0
Gasoline Volume (K Bbl/day)	1,022	68	161	1,251	674	348	229	1,251	478	544	229	1,251

Exhibit 6: Estimated Savings in Refining Costs and Investment from a California Oxygen Waiver, by Case

Summer Season

Type of Ban/Cost	Model Formulation: No Unocal Patent, Pool Flat Limits, Fixed Property Deltas: 2.0 wt% Oxygen	Model Formulation: No Unocal Patent, Pool Flat Limits, Fixed Property Deltas: 2.7 wt% Oxygen	Model Formulation: Unocal Patent, Grade-by-Grade Flat Limits, Variable Property Deltas: 2.0 wt% Oxygen	Model Formulation: Unocal Patent, Grade-by-Grade Flat Limits, Variable Property Deltas: 2.7 wt% Oxygen
California Ban				
Variable Cost & Capital Charge (¢/gal)	1.3	0.2	1.0	0.2
Investment ($MM)	79	78	-48	33
National Ban				
Variable Cost & Capital Charge (¢/gal)	2.0	1.1	1.8	0.8
Investment ($MM)	-15	87	-174	-76

California Environmental Protection Agency
Air Resources Board

Draft Assessment of the Real-World Impacts of Commingling California Phase 3 Reformulated Gasoline

August 2003

State of California
<u>California Environmental Protection Agency</u>

AIR RESOURCES BOARD
Stationary Source Division

Draft Assessment of the Real-World Impacts of Commingling California Phase 3 Reformulated Gasoline

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Acknowledgements

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I. EXECUTIVE SUMMARY

A. Introduction

There is an evaporative emissions effect associated with the mixing (or commingling) of a gasoline containing ethanol and a gasoline not containing ethanol. The addition of ethanol to a non-ethanol-blended fuel can increase the Reid vapor pressure (RVP) of the fuel by up to one pound per square-inch (psi). However, this impact is less when a fuel produced without ethanol is commingled with a fuel produced with (already containing) ethanol. This is because the RVP increase from commingling is limited to that which occurs in the fuel produced without ethanol (the RVP increase has already been realized in the ethanol-produced fuel). In this case, the commingling impact is dependent upon the relative proportions of each fuel in the final commingled fuel, as well as the ethanol content of the fuel produced with ethanol. Because of this, for example, the maximum RVP increase of commingling a 6 percent ethanol fuel is about 0.7 psi RVP, based on the addition of ⅔ of a tank of non-ethanol fuel to ⅓ of a tank of ethanol fuel.

Due to the RVP increase associated with commingling, the federal reformulated gasoline (RFG) regulations prohibit the mixing of ethanol blended gasoline and non-ethanol blended gasoline in the distribution and marketing system. However, neither the federal nor the California Phase 3 Reformulated Gasoline (CaRFG3) regulations prohibit the mixing of ethanol-blended gasoline with non-ethanol-blended gasoline in vehicle tanks. To date, since virtually all CaRFG has been made with methyl tertiary butyl ether (MTBE) and little ethanol, this has not been a significant problem in California. However, as MTBE is phased out of California gasoline, the mixing of a non-ethanol-blended fuel and an ethanol-blended fuel in vehicle tanks could result in a significant new source of emissions.

In proposing the CaRFG3 regulations in 1999, staff of the Air Resources Board (ARB/Board) estimated that the potential impacts of commingling CaRFG3 containing ethanol with CaRFG3 not containing ethanol in motor vehicle fuel tanks would result in an average 0.1 psi or less RVP increase in the California gasoline pool. An increase in the RVP of a gasoline has the practical effect of increasing evaporative emissions from motor vehicles. To compensate for the anticipated increase in evaporative emissions due to commingling, the CaRFG3 regulations include a reduced RVP flat limit for gasoline produced using the revised CaRFG3 Predictive Model. However, due to uncertainty in the potential commingling impacts, in approving the CaRFG3 regulations, the Board directed staff to further evaluate the magnitude of the potential real-world commingling impacts. Staff has completed this further evaluation, and this report presents their findings.

In addition, the United States Environmental Protection Agency (U.S. EPA) based its denial of California's request for a waiver from the federal oxygenate mandate on its belief that California may have underestimated the emissions associated with commingling. As a result, staff's evaluation not only addresses the Board's directive, but also collects data to address U.S. EPA's concerns about the likely emissions due to commingling.

B. Findings

Staff performed both simulation modeling and a field study to carry out the Board's directive to assess the likely magnitude of commingling impacts associated with the switch to CaRFG3. Based on the simulation model and field study, staff estimate that the likely overall RVP increase due to commingling is less than 0.1 psi. As such, the 0.1 psi RVP reduction provided for in the CaRFG3 Predictive Model is sufficiently protective against an increase in commingling evaporative emissions from gasoline powered motor vehicles.

Based on ethanol market share of 25 to 65 percent, the modeling work estimated average RVP increases of 0.06-0.07 psi and 0.06-0.08 psi, for 6 and 7.7 volume percent ethanol blends, respectively. Staff also investigated the sensitivity of the simulation model results by varying the assumptions for consumers purchase propensity toward ethanol fuel. The sensitivity analysis yielded ± 0.01 psi RVP variations to the above estimates. These figures are in good agreement with the field study results that found the likely commingling impacts were a statewide gasoline pool RVP increase of 0.06-0.13 psi, with the most likely statewide impact approximately 0.07psi RVP.

The results of ARB's recent commingling study, based on data collected specific to the California market place, demonstrates that the original ARB estimated commingling impact of no more than 0.1 psi increase in RVP in the California gasoline pool is correct, and that U.S. EPA's denial of California's waiver request was inappropriate.

C. Field Study

The first part of staff's evaluation consisted of a field study to collect fuel samples from in-use vehicle fuel tanks to provide information on the RVP of the gasoline before fueling. After fueling, a second sample was obtained to provide information on the increase in RVP due to commingling.

The general approach to obtaining these samples was to have sampling teams present at retail gasoline stations as consumers arrived to fuel their vehicles. Once permission from the vehicle operator was obtained, fuel samples were then taken from vehicle fuel tanks both before and after the vehicles were fueled. In order to determine the properties of the fuel being used for fueling the vehicles, morning and afternoon fuel samples were obtained from the gasoline station dispensers. During the sampling, descriptive information (such as initial vehicle fuel tank level, amount of fuel purchased, vehicle type, etc) specific to each fueling event was also collected. The fuel samples were then analyzed for RVP, oxygenate concentration, and total oxygen content to determine the actual impacts associated with commingling.

During the months of August and September 2001 staff implemented the fuel sampling protocol in three regions of the state: Lake Tahoe, the Bay Area, and Los Angeles. Sampling was performed at a total of 19 different gasoline stations resulting in data collection for 396 observed fueling events. Four of the 19 stations were dispensing ethanol-blended fuel. As anticipated, staff was unable to successfully obtain fuel samples from every vehicle due to various fill-pipe configuration constraints. Of the 396 observed fuelings, 254 complete sets of fuel samples were obtained for an overall sampling success rate of 64 percent. The model year of vehicles in the sample is representative of the 2001 statewide passenger car and light-duty truck population.

D. Consumer Fueling Habits

The second part of staff's evaluation included gathering information on California consumer fueling habits. Fueling habits are a critical factor in the evaluation of commingling impacts. Therefore, it was essential to collect current information specific to California consumers.

Data collected during the field study portion of staff's evaluation allow observation of several fueling habits critical to estimating commingling impacts. To supplement the field information, staff requested gasoline marketers to provide additional information on motorists fueling habits. Based on the information provided by California gasoline marketers, staff believes that the fueling data collected in the field study are sufficiently representative of California consumers for use in a commingling analysis.

E. Simulation Model

In addition to documenting actual impacts of commingling on individual vehicle fuel tanks from data of the field study, a simulation model was used to estimate the potential commingling impacts. The simulation model used was developed by Dr. David M. Rocke, University of California, Davis.

The actual impact on emissions of commingling depends on many variables associated with the gasoline marketplace and on consumer behavioral patterns. These include ethanol market penetration, brand loyalty, fuel tank levels prior to fueling, fillup vs. non-fillup preference, and quantity of fuel purchased. For staff's modeling analysis, the potential future ethanol market share was assumed to vary from 25 percent to 65 percent of the gasoline market pool.

The field study data drive the simulation model with the following input parameters:

- overall, almost 50 percent of consumers purchase the same gasoline brand as their previous fuel purchase;
- about 80 percent of consumers fuel when there is ¼ tank of gasoline or less remaining in their tanks, with more than 40 percent registering nearly an empty tank;
- more than 50 percent of consumers opt for fillup, and;
- non-fillup consumers purchase on average 7 gallons of fuel, about 1/3 to ½ of an average tank, assuming most tanks have a capacity between 14 and 20 gallons.

These figures are consistent with data identified in previous commingling studies, including those by the U.S. EPA staff.[1]

F. Analysis of U.S. EPA Denial of California's Waiver Request

On April 12, 1999, Governor Davis requested a waiver from the U.S. EPA from the federal oxygen requirement for federal reformulated gasoline areas. Additional information supporting the waiver request was submitted to the U.S. EPA as necessary. The justification for a waiver request was based on the fact that the use of oxygenates, such as ethanol, increases emissions of oxides of nitrogen (NOx). As a result, the federal oxygen requirement interferes with the ability of California to meet the national ambient air quality standards (NAAQS) for ozone and particulate matter (PM), where NOx is a precursor to both ozone and PM. The CaRFG3 Predictive Model clearly demonstrates that non-oxygenated fuels can be produced which provide additional NOx reductions for the state.

In June 2001, the U.S. EPA denied California's waiver request. In denying the waiver, the U.S. EPA acknowledged the NOx benefits of non-oxygenated fuels, but believed that there was too much uncertainty regarding potential increases in volatile organic compound (VOC) evaporative emissions. The U.S. EPA associated this uncertainty with uncertainty concerning the magnitude of emissions increase due to fuel commingling in vehicle fuel tanks, especially in the South Coast Air Quality Management District (SCAQMD).

The ARB field study data of California consumer fueling habits (brand loyalty, initial tank level, and frequency of fillup) are similar to the information possessed by the U.S. EPA. However, in their analysis of commingling U.S. EPA staff modified the data, because of a stated lack of confidence that the data adequately represent actual fueling habits. This modification produced lower brand loyalty, lower percent of fillups, and higher initial fuel tank levels. Each of these changes leads to a higher commingling effect. Moreover, there is a distinct difference between the ARB's and U.S. EPA's analysis in the way "brand-loyal" consumers (those who always purchase one brand of gasoline) are handled. While the ARB assumed negligible commingling effects from this group of consumers, the U.S. EPA assumed the group would contribute to commingling.

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[1] In-Use Volatility Impact of Commingling Ethanol and Non-Ethanol Fuels", Peter Caffrey and Paul Machiele, U.S. EPA, Society of Automotive Engineers (SAE) Paper 940765

Cumulatively, these factors produced an over estimation of potential commingling impacts by the U.S. EPA staff, at least, by a factor of two.

II. INTRODUCTION

This chapter provides information on the current requirements for gasoline sold in California, the State's phase out of MTBE, and California's request for a waiver from the federal oxygen mandate for federal RFG.

A. Current Requirements for California Gasoline

Both state and federal regulations govern California gasoline production.

1. California Regulations

The California Phase 2 Reformulated Gasoline (CaRFG2) regulations were adopted by the ARB in 1991 and were implemented in 1996. These regulations established a comprehensive set of specifications, including limits for eight gasoline properties, including:

- Reid vapor pressure
- Sulfur content
- Benzene content
- Aromatics content
- Olefins content
- 50 percent distillation point (T50)
- 90 percent distillation point (T90)
- Oxygen content

The CaRFG2 regulations have provided very significant reductions in ozone and particulate matter precursor emissions and toxic air pollutants. The emission benefits of the program have been equivalent to removing 3.5 million vehicles from California's roads.

2. Federal Regulations

California gasoline production is also governed by federal RFG regulations enacted by the U.S. EPA. Nationally, about 30 percent of the gasoline produced must meet these requirements. These regulations impose emission performance standards in conjunction with specific requirements for oxygen content (year-round average of 2.0 percent by weight), and limits on benzene content. The federal requirements were implemented in two phases. The first phase began in 1995 and the second phase began in December 1999. In the September 15, 1999 Federal Register, the U.S. EPA made the finding that the emission reduction benefits of California gasoline are at least as great as those from federal Phase II RFG.

For California, the federal RFG regulations were first implemented in 1995 in the South Coast and San Diego and in 1996 in the Sacramento Metropolitan Region. The South Coast, San Diego, and Sacramento areas of the State account for about 70 percent of the gasoline sold in California. Further, the San Joaquin Valley was recently reclassified by the U.S. EPA as a "severe" ozone non-attainment area and this region has used federal RFG since December 10, 2002. With the San Joaquin Valley included in the federal RFG program, approximately 80 percent of the gasoline sold in California will need to meet both the federal and the more stringent state gasoline requirements.

Because of the 1990 federal Clean Air Act Amendments (CAAA) requirement that mandated the use of a minimum oxygen content, the use of oxygenates in California, and MTBE in particular, has grown significantly.

B. California Phase 3 Reformulated Gasoline

Because of concerns regarding the use of MTBE, on March 25 1999, Governor Gray Davis issued Executive Order D-5-99 which, among other things, called for the phase-out of MTBE no later than December 31, 2002. The Governor's Executive Order also directed the ARB to adopt CaRFG3 regulations that will provide additional flexibility in lowering or removing the oxygen content requirement while maintaining the emissions and air quality benefits of CaRFG2, and that the U.S. EPA be requested to provide a waiver from the federal oxygen mandate in California.

In December 1999, the ARB approved the CaRFG3 regulations. These regulations were designed to prohibit the use of MTBE in the production of California gasoline while preserving the benefits of the CaRFG2 program. They were also designed to provide additional flexibility to refiners to produce California gasoline. The CaRFG3 specifications are shown in Table II-1.

With the approval of the CaRFG3 regulations, ethanol is the only oxygenate approved to replace MTBE in California. Therefore, the phase out of MTBE is expected to result in large-scale replacement of MTBE with ethanol to comply with the federal RFG oxygen requirement. The addition of ethanol to gasoline results in a non-linear increase in the fuel's RVP. An RVP increase also results when ethanol blended gasoline is added to non-ethanol blended gasoline. This is called commingling, and the resulting RVP increase is called the commingling impact. In general, commingling results in an increase in evaporative VOC emissions from motor vehicles. In order to maintain the emissions and air quality benefits of the CaRFG2 program, the ARB included a reduction in the CaRFG3 Predictive Model[2] RVP fuel specification of 0.1 psi to offset the anticipated impacts associated with commingling.

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[2] The Predictive Model is a mathematical set of equations that relate emission rates of certain pollutants to the values of the eight regulated gasoline properties. To date, most gasoline produced from refineries in California has been produced according to the Predictive Model.

Table II-1:
California Reformulated Gasoline Phase 3 Specifications

Property	Units	Flat Limits	Averaging Limits	Cap Limits
Reid Vapor Pressure[1]	psi	7.00 or 6.90[2]	Not Applicable	6.40 – 7.20
Sulfur Content	ppmw	20	15	60[3] 30[3]
Benzene Content	Volume %	0.80	0.70	1.10
Aromatics Content	Volume %	25.0	22.0	35.0
Olefins Content	Volume %	6.0	4.0	10.0
T50	°F	213	203	225
T90	°F	305	295	335
Oxygen Content	Weight %	1.8 - 2.2	Not Applicable	0 – 3.7

[1] The Reid vapor pressure standards apply only during the summer months.

[2] The 6.90 psi standard applies only when a producer or importer is using the evaporative emissions model element of the CaRFG Phase 3 Predictive Model.

[3] The CaRFG Phase 3 sulfur content cap limits of 60 and 30 parts per million are phased in starting December 31, 2002, and December 31, 2004, respectively.

However, due to uncertainty in the potential commingling impacts, in approving the CaRFG3 regulations, the Board directed staff to further evaluate the real-world impacts of commingling. Staff's efforts to evaluate these impacts are described in Chapters III through VII.

C. California's Waiver Request

On April 12, 1999, Governor Davis requested a waiver from the U.S. EPA from the federal oxygen requirement for federal reformulated gasoline areas. Additional information supporting the waiver request was submitted to the U.S. EPA as necessary. The justification for a waiver request was based on the fact that the use of oxygenates, such as ethanol, increases emissions of NOx from gasoline powered motor vehicles. As a result, the federal oxygen requirement interferes with the ability of California to meet the NAAQS for ozone and PM, where NOx is a precursor to both ozone and PM. The CaRFG3 Predictive Model demonstrates that non-oxygenated fuels can be produced which provide additional NOx reductions for the state.

In June 2001, the U.S. EPA denied California's waiver request. In denying the waiver, the U.S. EPA acknowledged the NOx benefits of non-oxygenated fuels, but believed that there was too much uncertainty regarding potential increases in VOC evaporative emissions from commingling in vehicle fuel tanks, especially in the SCAQMD. Staff's evaluation and analysis of U.S. EPA's denial of California's waiver request is provided in Chapter VIII.

D. Executive Order D-52-02

Because of the U.S. EPA's decision to deny California's waiver request, between 750 and 900 million gallons of ethanol will need to be imported into the state each year as soon as the ban on MTBE is implemented. The California Energy Commission (CEC) and independent consultants have questioned whether the necessary quantity of ethanol could be efficiently transported to and distributed within California by 2003. In February 2002, an independent study commissioned by the CEC advised that price spikes of up to 100 percent are likely if MTBE is phased out with an inadequate supply of ethanol available and ready for distribution. The independent study also emphasized that even with an adequate supply of ethanol available and ready for distribution, phasing out MTBE next year could result in a five to ten percent shortage of gasoline. In 1999, California experienced a supply reduction of similar magnitude due to major fires and facility outages at two California refineries, and the price of gasoline nearly doubled.

As a result, on March 15, 2002, Governor Davis issued Executive Order D-52-02 that directs the ARB, by no later than July 31,2002, to provide California refineries an additional twelve months for the transition from MTBE to ethanol in gasoline. Under the newly announced timeline, the MTBE phase-out will be accomplished no later than December 31, 2003. Individual refineries may continue to make the transition to ethanol earlier than December 2003.

In July 2002, the ARB approved the amendments to the CaRFG3 regulations. The amendments include a postponement of the prohibition of MTBE and other oxygenates use in California gasoline, other than ethanol, supplied by refiners and importers from December 31, 2002 to December 31, 2003.

III. DESIGN AND IMPLEMENTATION OF THE FIELD STUDY AND OTHER DATA COLLECTION EFFORTS

In better defining the impacts of commingling in California markets, ARB conducted both a field study and simulation modeling. This chapter describes the design and implementation of the ARB field study to evaluate the real-world impacts of commingling, including staff's efforts to collect specific information on California consumer fueling habits.

A. ARB Field Study

The first component of staff's evaluation of the real-world impacts of commingling CaRFG3 was the implementation of a field study. The field study was intended to collect real-world information regarding commingling in vehicle fuel tanks, as well as specific information on consumer fueling habits.

1. Establishment of ARB/Industry Working Group

In developing the scope and mission of a field study, staff formed an ARB/industry working group in April 2001. This working group was comprised of representatives from the ARB staff and the oil, ethanol and automotive industries. A list of the companies and organizations represented in the working group is provided in Appendix A. Between April and November 2001 the working group met four times.

Staff also used the working group to provide technical comments regarding staff's analysis. In April 2002, staff provided a preliminary draft version of staff's analysis to the working group for comment and feedback. Staff then made appropriate changes to the analysis based on the working group's comments. Appendix B contains the comments received from the working group by staff.

2. Development of Field Study Protocol

Staff's goal in conducting a field study was to collect fuel samples from motorist's fuel tanks to estimate base fuel RVP as well as verify the estimated increase in RVP due to commingling. In developing a field study, staff was interested in collecting the following information:

- Initial RVP of vehicle fuel tank (prior to fueling).
- RVP of dispensed fuel.
- Final RVP of vehicle fuel tank (after fueling).
- Total oxygen content of each fuel sample.
- Oxygenate types and concentration for each fuel sample.

- Consumer information (such as initial vehicle fuel tank level, amount of fuel purchased, vehicle type, etc).

Fuel Sampling Protocol: Staff's initial efforts to implement a field study began with the development of fuel sampling protocol. The general approach to obtaining these samples was to have sampling teams present at retail gasoline stations as consumers arrived to fuel their vehicles. Fuel samples collected through a chilling apparatus were then taken from vehicle fuel tanks both before and after the vehicles were fueled. In order to determine the properties of the fuel being used for fueling the vehicles, morning and afternoon fuel samples were obtained from the gasoline station dispensers. During the sampling, descriptive information (such as initial vehicle fuel tank level, amount of fuel purchased, vehicle type, etc) specific to each fueling event was also collected and noted on field data sheets. The fuel samples were then analyzed for RVP, oxygenate concentration and total oxygen content to determine the actual impacts associated with commingling.

While the field study was conceptually straightforward, due to the unique nature of such a fuel-sampling program, a standardized approved sampling protocol did not exist. Therefore, the primary focus of the first three working group meetings was the development of an appropriate protocol. By using various components of existing American Society of Testing and Materials (ASTM) and ARB fuel sampling test methods, staff was able to develop an effective fuel sampling protocol that was accepted by the working group for final implementation.

Samples from the vehicle tanks and the station's underground tanks were obtained using ASTM D 5842-95, "Standard Practice for Sampling and Handling of Fuels for Volatility Measurement". Since vehicle tanks are not mentioned in the ASTM sampling method, staff utilized the tank tap portion of ASTM D 5842-95, modified using apparatus that ARB has successfully used for some time to obtain diesel samples from vehicle tanks to check for presence of red dye. Special care, including cooling the sample line and sample container in an ice bath, was taken to ensure that minimal evaporation took place during the sampling process so that accurate RVP results were obtained.

Prior to the final implementation of the fuel sampling protocol, a trial run was performed to evaluate the efficacy of the protocol and to provide sampling staff the opportunity to gain experience and familiarity with the sampling procedure. Staff spent two days in the field conducting sampling operations at six different gas stations. Based on the trial run efforts, minor revisions were incorporated into the fuel sampling protocol.

The final fuel sampling protocol is provided in Appendix C.

Fuel Sample Analysis: Fuel sample analysis was performed by laboratory staff of the ARB. To minimize the amount of handling and the duration of sample storage prior to RVP analysis, the fuel samples were analyzed for RVP within 24 hours in the ARB's mobile laboratory that was located in the general vicinity of the stations participating in the field study. All samples were analyzed for RVP using ARB's "Test Method for the

Determination of the Reid Vapor Pressure Equivalent Using an Automated Vapor Pressure Test Instrument" (California Code of Regulation (CCR) Title 13 §2297).

After analysis for RVP in the ARB's mobile laboratory, the fuel samples were transported to the ARB's laboratory facilities in El Monte, California. There, the fuel samples were analyzed for the volumetric amount and type of oxygenate (MTBE, tertiary amyl methyl ether (TAME), and ethanol) as well as total oxygen content, by ASTM D 4815-94, "Standard Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C1 to C4 Alcohols in Gasoline by Gas Chromatography".

Table III-1 provides a summary of the fuel properties analyzed and the analysis method used.

Table III-1:
Methodology for Fuel Sample Analysis

Fuel Property	*Units*	*Analysis Method*
RVP	psi	CCR, Title 13 §2297[1]
Oxygen Content	Weight %	ASTM D 4815-94
Ethanol Content	Volume %	ASTM D 4815-94
MTBE Content	Volume %	ASTM D 4815-94
TAME Content	Volume %	ASTM D 4815-94

[1] Paragraph (d)(1.0) which specifies a CCR, Title 13 sampling method will be replaced with ASTM D 5842 sampling method which allows for the use of either 32-oz or 4-oz bottles.

3. Field Study Areas, Sampling Sites, and Field Sampling

This section describes the areas selected for inclusion in the field study, the sampling sites selected (including station brand and location) and a discussion of staff's field sampling experience.

Field Study Areas: The production, distribution, and marketing of gasoline in California is essentially divided into two regions, north and south. Refineries in the Los Angeles area supply the majority of the gasoline used in southern California, and most of the gasoline used in northern California is supplied by refineries in the Bay Area. These two large metropolitan areas also account for a large portion of the regional demands. It was therefore decided that the field study would include each of these areas.

Although at the time there were ethanol-blended fuels being marketed throughout California, they represented only a small fraction of the total statewide supply. However, due to the voluntary early phase out of MTBE, ethanol blended fuels were much more prevalent in the Lake Tahoe area. Therefore, in order to increase the number of potential commingling events observed during the field sampling, it was decided this area would also be included in the field study.

Sampling Sites: In identifying potential sampling sites (gas stations) to include in the field study, California gasoline marketers were asked to provide staff access to stations in each area. Participation in the field study was purely voluntary on the part of each gasoline marketer. However, in selecting sampling sites, staff attempted to include stations dispensing ethanol-blended fuels and non-oxygenated fuels.

In the Lake Tahoe area, nine stations were selected for participation in the field study. Four sampling sites in the Lake Tahoe area were dispensing ethanol-blended fuels, and five stations were dispensing non-oxygenated fuels. The following fuel brands were included as part of the field study in the Lake Tahoe area:

- **Lake Tahoe Area** (Kings Beach and South Lake Tahoe)
  - ➢ Beacon (2 different stations)
  - ➢ Chevron
  - ➢ Shell (2 different stations)
  - ➢ USA Gasoline (2 different stations)
  - ➢ Fox Gasoline
  - ➢ United Gasoline

In the Bay Area, six stations were selected for participation in the field study. Because of the voluntary approach to the field study, staff was unable to secure any sampling sites dispensing ethanol-blended fuels. However, two stations were dispensing non-oxygenated regular and mid-grade gasoline. The following fuel brands were included as part of the field study in the San Francisco Bay area:

- ➢ **The Bay Area** (Campbell, Los Gatos, San Jose, Sunnyvale, and Cupertino)
  - ➢ ARCO
  - ➢ Chevron (2 different stations)
  - ➢ Shell (2 different stations)
  - ➢ Valero

In the Los Angeles area, four stations were selected for participation in the field study. Staff had originally planned to include six stations in their assessment. However, because the planned sampling schedule included September 11, 2001, staff was unable to perform field sampling on that day. Similar to the Bay Area sampling, due to the voluntary approach to the field study, staff was unable to secure any sampling sites dispensing ethanol-blended fuels. All of the Los Angeles area stations were dispensing oxygenated fuels containing MTBE. The following fuel brands were included as part of the field study in the Los Angeles area:

- Los Angeles Area (Hacienda Heights, Azusa, and Glendora)
    - ARCO
    - Chevron
    - Mobil
    - Texaco

Field Sampling: During the months of August and September 2001 staff implemented the fuel sampling protocol in the three areas of the state: Lake Tahoe, the Bay Area, and Los Angeles. Sampling was performed at a total of 19 different gasoline stations resulting in data collection for 396 observed fuelings. Four of the 19 stations were dispensing ethanol-blended fuel. In general, consumers were very willing to participate in the field study program. However, as anticipated, staff was unable to successfully obtain fuel samples from every vehicle due to various fill-pipe configuration constraints. Of the 396 vehicles participating in the field study, fuel samples were obtained from 254 vehicles (before and after fueling samples from the vehicle fuel tank) for an overall statewide sampling success rate of 64 percent. This information is shown in Table III-2.

Table III-2:
Field Sampling Results by Region

Region	No. of Stations				Number of Vehicles Participating	Number of Vehicles Sampled
	Oxy/MTBE[1]	Non-Oxy	Ethanol	Total		
Lake Tahoe	0	5	4	9	175	121
The Bay Area	4	2[2]	0	6	121	79
Los Angeles	4	0	0	4	100	54
Statewide Total	8	7	4	19	396	254

[1] Some of fuel dispensed from stations identified as MTBE also contained TAME.

[2] These stations only sold non-oxygenated fuel in their regular and mid-grade gasoline. Their premium grade of gasoline was oxygenated with MTBE.

B. Data Collection on California Consumer Fueling Habits

The second part of staff's evaluation of the real-world impacts of commingling CaRFG3 included gathering information on California consumer fueling habits. Fueling habits are a critical factor in the evaluation of commingling impacts. Data available on consumer fueling habits prior to the start of the field study were either dated and/or not specific to

California consumers. Therefore, it was essential to collect current information specific to California consumers.

Data collected during the field study portion of staff's evaluation allowed estimation of California motorists fueling habits. Information collected included:

- Whether the consumer purchased the same brand of gasoline during their previous fueling
- Initial fuel tank level
- Whether the fueling event was a "fillup" or not
- Volume of fuel purchased
- Dollar amount of fuel purchased

To supplement the field information, staff requested gasoline marketers to provide additional information on motorists fueling habits. Based on the information provided by California gasoline marketers, staff believes that the fueling data collected in the field study are sufficiently representative of California consumers for use in the commingling evaluation.

C. Data Handling and Quality Control

In collecting the field study data, staff established uniform data handling procedures to ensure no losses in the data collected. In addition, thorough data quality assurance and quality control procedures were utilized during all phases of the evaluation to ensure the accuracy and completeness of the data.

1. Data Handling

In conducting the field study, two sets of data were collected. The first set of data, referred to as the field data sheets, contained the information collected in the field. These data consisted of the specific vehicle fueling information that was documented as well as information to identify specific fuel samples (before and after fueling) to a particular vehicle fueling. The field data collected were key data entered into a spreadsheet at the completion of the fieldwork.

The second data set was the results of the fuel analysis performed by the ARB laboratory staff. Data from the RVP fuel analysis were provided as paper printouts generated by the analytical equipment, with each data set identifying the fuel sample number, as referenced on the field data sheet. These data were key data entered into a spreadsheet for use in staff's analysis of the field study data results. The data generated from the oxygen and oxygenate fuel analysis were provided by the ARB laboratory staff in a spreadsheet format, also referenced by fuel sample number. Once all the fuel sample analysis data were received, these data were merged with the field data collected into a single main data file.

2. Data Quality Assurance/Quality Control

Data quality assurance and quality control were practiced in the field during the implementation of the field study, in the laboratory during analysis of the fuel samples, and during key data entry of the field data.

Field Work: In conducting the field study, various techniques were employed to assure the quality of the field operations. All staff involved in the field operations were thoroughly trained in the proper implementation of the fuel sampling protocol. As part of this training, staff spent several hours practicing the fuel sampling procedure on state-owned vehicles located at the Department of General Services garage in Sacramento. Additional experience was obtained by conducting a two-day trial run in the Bay Area. During the trial run, three sampling teams were deployed, conducting sampling operations at six different gasoline stations. The two-day trial provided invaluable experience, not only in actual vehicle fuel tank sampling, but also in how to successfully approach private vehicle owners to obtain their voluntary participation. Obtaining volunteers in a timely fashion was critical in the conduct of the field operations.

During the field operations, all sampling team members met on a daily basis to discuss the previous day's activities. The composition of each sampling team was varied by rotating individual team members on a daily basis. As resources allowed, an additional member of the field staff performed oversight activities at all sampling sites. Oversight activities included helping individual teams with any sampling equipment needs (such as maintenance or misplaced tools) in addition to critiquing individual team performance. All field data sheets were reviewed at the end of each day for consistent proper completion; any resultant questions or concerns were discussed immediately with associated team members.

Laboratory Analysis: All quality assurance procedures were followed as described in the applicable ASTM methods. Also, ARB laboratory staff followed appropriate sampling and analytical quality control procedures, as contained in the Standard Operating Procedures (SOPs) for the fuel methods as described below. Data on the quarterly quality control activities of the ARB laboratories are available.

Reid Vapor Pressure Equivalent (SOP MLD 125): At the beginning of each analysis day, a standard material (usually 2,3-dimethylbutane) was analyzed on each vapor pressure instrument. The absolute vapor pressure of the standard material must not differ from the published value by more than 0.15 psi.

Oxygenates in Gasoline (SOP MLD 115): Quality control for this test method occured in three areas:

1. A quality control standard of known composition was analyzed at the beginning and end of each day's analyses. The QC standard was also run after every 10 samples if more than 10 samples were being analyzed at one time. The QC standard's measured concentrations of MTBE, TAME, and ethanol must not differ

from the known concentrations by more than twice the published repeatability of ASTM D4815.

2. A blank sample was run at the beginning of each day's analyses. The measured concentrations of MTBE, TAME, and ethanol in the blank sample must not be higher than 0.1 mass percent.

3. One sample out of every 10 was analyzed twice in succession. The difference in oxygenate concentrations measured in the two runs must not exceed the repeatability of ASTM D4815.

Data Entry: All hard copy of data was reviewed for any apparent errors prior to key data entry. Once key data entry was complete, the electronic data file was spot checked against the original hard copy for correctness. After all the data were entered into one master spreadsheet file, various additional methods (such as filtering, sorting, and statistical analysis) were used to further audit the data quality.

IV. FIELD STUDY DATA AND CONSUMER FUELING HABITS

This chapter discusses staff's observations in the field study. It includes information on the field study data, the representativeness of the sampled vehicles, and the range of gasoline specifications observed. Also included is staff's findings regarding California consumer fueling habits. These fueling habits include information on brand loyalty, initial fuel tank levels, fillup frequency, and grade purchasing propensity.

A. Field Study Data

A complete set of the field study data is contained in Appendix D. This data set includes both the individual information compiled from the field data sheets, as well as the fuel analysis information provided by ARB laboratory staff. The two data sets have been paired so that the fuel analysis information is associated with the information collected on a particular field data sheet. However, based on deliberations in the working group, gasoline brand information is not presented in the field study data contained in Appendix D.

B. Representativeness of Sampled Vehicles

In evaluating the field study data, staff was interested in determining if the age of the sampled vehicles was representative of the statewide vehicle population. This comparison is important to ensure that the vehicles observed in the field study are representative of the increasingly sophisticated emission control equipment found on more modern vehicles.

To perform this evaluation, staff compared the relative age of the sampled vehicle in the field study to that of the 2001 California passenger car and light-duty truck population, as contained in the ARB motor vehicle emission inventory model, EMFAC 2000 (version 2.02) that was based on California Department of Motor Vehicle (DMV) registration data. Three observations involving two motorcycles and a ski boat were excluded. This comparison is shown in Table IV-1, with vehicle age represented in five-year increments. As can be seen, the vehicle model years observed in each region are comparable to each other. The overall sample population is very similar to the statewide vehicle population as contained in EMFAC 2000, which is indicative of the representativeness of the field study data to the California passenger car and light-duty truck population.

**Table IV-1:
Vehicle Model Year Comparison Between
EMFAC 2000 and the ARB Field Study**

Vehicle Age (Years)	Percentage of Vehicles Represented				
	Lake Tahoe	The Bay Area	Los Angeles	Overall	EMFAC 2000 (Ver. 2.02)
1-5	34%	36%	30%	34%	31%
6-10	28%	31%	26%	29%	25%
11-15	18%	17%	15%	17%	23%
16-20	13%	8%	17%	12%	12%
21-25	3%	3%	5%	4%	4%
26-30	2%	2%	3%	2%	2%
> 30	2%	3%	4%	3%	3%
Total	100%	100%	100%	100%	100%

C. Field Observations of Dispensed Gasoline

In evaluating the commingling impacts observed during the field study, it is important to first identify the types of fuels being dispensed. Non-oxygenated gasoline was considered fuel that had an MTBE content of less than or equal to 0.6 volume percent and an ethanol content less than 0.5 volume percent. MTBE-blended fuel had an MTBE content greater than 0.6 volume percent, and ethanol-blended fuel had an ethanol content greater than or equal to 0.5 volume percent. This is summarized in Table IV-2, along with the observed oxygenate concentrations in MTBE produced and ethanol-blended fuels.

**Table IV-2:
Oxygenate Concentrations Observed in Field Study**

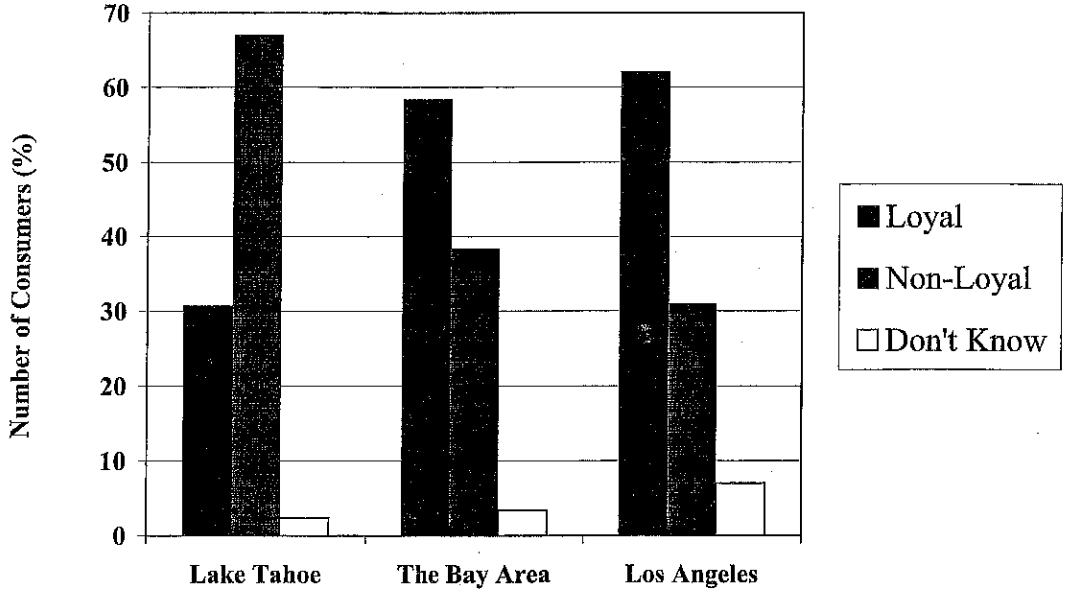
Fuel Type	Defining Oxygenate Concentration (Vol %)		Range of Oxygenate Observed (Vol %)	
	Ethanol	MTBE	Ethanol	MTBE
Non-Oxygenated	< 0.5	≤ 0.6	N/A	N/A
MTBE-Blended	< 0.5	>0.6	N/A	7.68 – 13.59
Ethanol-Blended	≥0.5	≤ 0.6	5.30 - 5.97	N/A

It is also important to note that typical California fuels being produced generally have an RVP of between 6.6 psi and 6.9 psi. The average dispensed fuel RVP measured in the field study was 6.76 psi. Fuels generally are not produced above 6.9 psi RVP to ensure that the fuel meets the summertime RVP cap of 7.0 psi currently in effect in California.

D. Characterization of Brand Loyalty

In conducting the field study, staff collected information on the brand loyalty of each consumer participating in the field study. In collecting these data, each consumer was asked if a different brand of gasoline was used for the last fueling of the vehicle. Each consumer response was recorded by staff on the field data sheet as either "yes", "no", or "don't know". For the purposes of staff's evaluation, "loyal" consumers were assumed to be those consumers who answered "no"; "non-loyal" consumers were assumed to be those consumers who answered "yes". These data are shown in Figure IV-1 for each of the three regions in the field study.

Figure IV-1. Gasoline Brand Loyalty* by Region



*Current and previous fuelings

As can be seen from Figure IV-1, in the Los Angeles and the Bay Area, over 50 percent of consumers participating in the field study identified themselves as loyal (used the same brand of gasoline as their previous fueling). In the Los Angeles area, this percentage was over 60 percent. Staff believes that the brand loyalty trend in these areas is indicative of consumers' normal, commuter type of behavior where they likely pass the same fueling stations each day. In these same areas, non-loyal consumers (those using a different brand of gasoline as their previous fueling) ranged between 30 and 40 percent, with less than 5 percent of consumers unsure of the previous brand of fuel used.

As compared to the Los Angeles and the Bay Area, the results in the Lake Tahoe area were significantly different. As can be seen in Figure IV-1, in the Lake Tahoe area the percentage of loyal consumers was slightly more than 30 percent, only about half the percentage as in Los Angeles and the Bay Area; conversely, the percentage of non-loyal consumers exceeded 65 percent, nearly twice that in these same two areas. In considering these results, this trend is expected since the Lake Tahoe region is a popular tourist destination, and there are fewer "major" brands of gasoline available in the region. Staff believes that the data are indicative of the need of non-local consumers to fuel in an unfamiliar area, thereby purchasing the most readily available fuel, regardless of brand. In reaching this conclusion, staff believes this pattern is likely atypical of a consumer's "normal" fuel purchasing patterns.

When the brand loyalty data in the Bay Area and Los Angeles were compared to the statewide data provided to the staff by gasoline marketers, the field study data were somewhat higher. Staff believes this is because the loyalty figure observed from the field study data may include some non-loyal consumers who happened to purchase the same brand of gasoline twice in a row as they were classified as consumers who "always" buy the same brand by default based on the wording of the field survey questionnaire.

Using data from the gasoline marketers, about 40 percent of California consumers always "use one gasoline brand," more than 50 percent "use two to three gasoline brands," and the remaining "use many gasoline brands." Rarely, do consumers make random brand switching. Most of the time, certain distinct patterns are followed. In the "use two to three brands" case, it is very likely that consumers use one brand for several consecutive fuelings, and occasionally switch to another brand. This hypothesis is supported by the field study data where brand loyal consumers represent a somewhat higher percentage than the "use one brand" case reported by the gasoline marketers. From a commingling stand point, the frequency with which consumers switch fuel types is important, not the number of brands being used. As any brand switching may not necessarily result in commingling when both brands are selling the same type of gasoline. Because of this, staff believes that the field study loyalty data are reasonable.

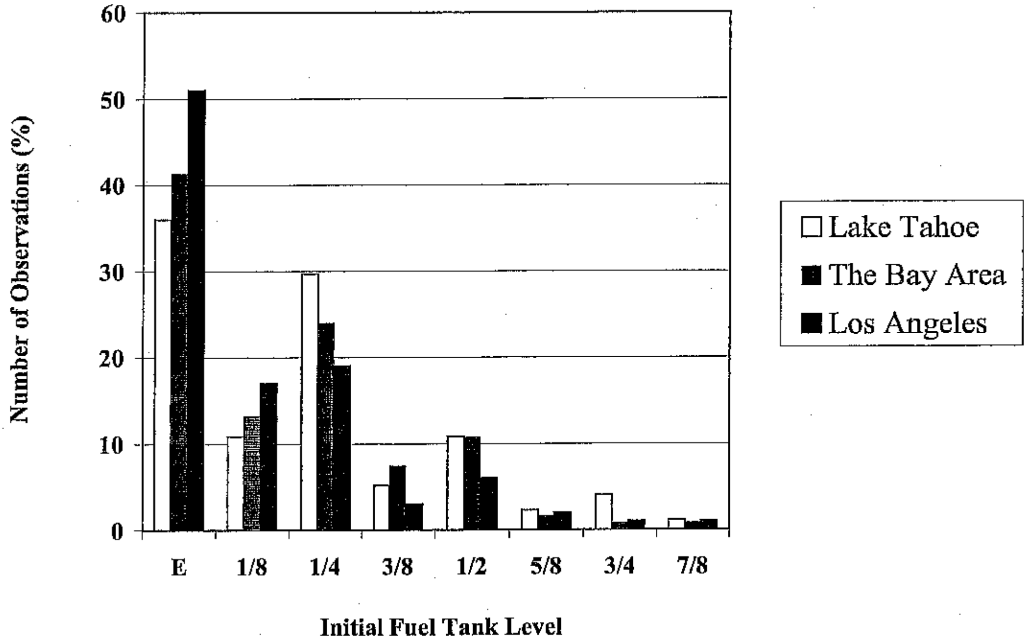
E. Initial Fuel Tank Levels

In conducting the field study, staff collected information on the initial fuel tank levels from each of the vehicles observed. The data are based on a visual observation of the fuel gauge display in the passenger compartment of the vehicle. These data are shown in Figure IV-2

As can be seen in Figure IV-2, almost 90 percent of the vehicles that were observed in Los Angeles region had fuel tank levels of a quarter tank or less when refueled, with about 50 percent registering near empty. In the Bay Area, almost 80 percent of the vehicles had a quarter tank or less, and 40 percent of the vehicles were nearly empty. However, since Lake Tahoe is generally a tourist destination, staff expected higher initial fuel tank levels due to visitors unfamiliarity with the region. The data support this hypothesis, with only about 35 percent of vehicles fueled at or near an empty tank. In general, though, initial fuel tank levels in each of the three regions were most often (nearly 80 percent) less than a quarter tank.

These data are consistent with a survey of over 1100 fuelings[3] by General Motors (GM). In the GM data, nearly 60 percent of the fuelings occurred with less than 0.2 of the fuel tank capacity remaining, and about 85 percent occurred with less than 0.3 of the fuel tank capacity remaining.

Figure IV-2. Distribution of Initial Fuel Tank Levels by Region



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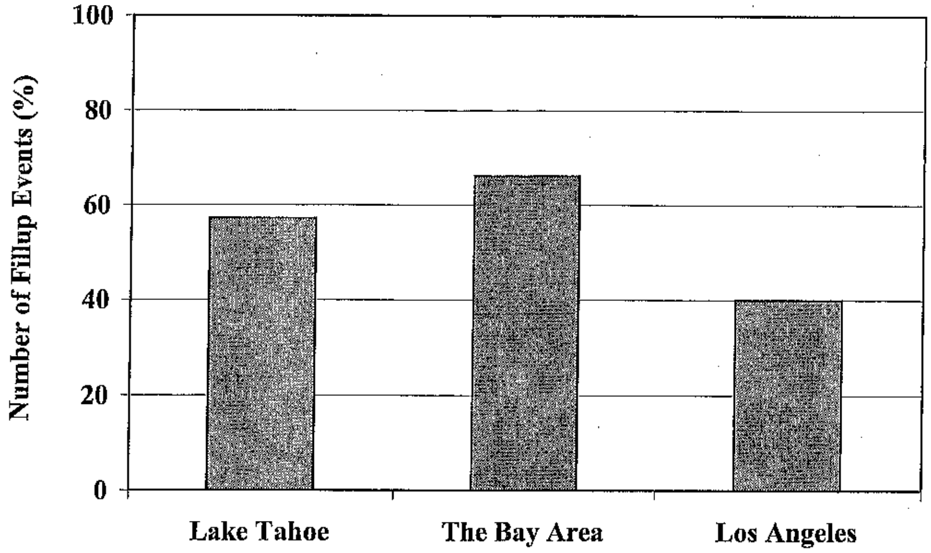
[3] "In-Use Volatility Impact of Commingling Ethanol and Non-Ethanol Fuels", Peter Caffrey and Paul Machiele, U.S. EPA, Society of Automotive Engineers (SAE) Paper 940765.

F. Characterization of Fueling Events

In conducting the field study, staff also collected information regarding the characterization of fuelings. For this information, staff collected information on consumer fuel purchasing patterns regarding the amount of fuel purchased. This information is shown below in Figure IV-3.

Figure IV-3. Fillup Events by Region



In the field study, a "fillup" was recorded as a fueling event where the activation of the gasoline dispenser's automatic shut-off function was observed. As can be seen in Figure IV-3, the highest percentage of fillup events occurred in the Bay Area (over 65 percent), and the fewest fillup events were observed in the Los Angeles area (40 percent) while the Lake Tahoe area figure was in between. Staff believes this translates into about a 50 percent fillup rate within the State.

Similar to the initial vehicle fuel tank levels observed, the overall data for these three areas combined are consistent with the GM data reported by Caffrey and Machiele (SAE 940765). In that work, fillup (as represented by a final fuel tank level after fueling of 90 or 100 percent of capacity) events represented were nearly 50 percent of the 1,100 fuelings recorded.

G. Gasoline Grade Preference

In conducting the field study, staff recorded information on the grade of gasoline purchased for each fueling event observed. Staff then compared this to available data from the U.S. Department of Energy (U.S. DOE) regarding gasoline sales by grade in California[4], averaged over the same two month period that coincided with the implementation of the field study. These data are provided in Table IV-3, which shows the percent of consumers purchasing each of the three grades of gasoline available in California by region. As can be seen from Table IV-3, the overall vehicle fueling observations in the field study (by grade) are comparable to the U.S. DOE data of the statewide gasoline consumption.

**Table IV-3:
Grade Selection Comparison Between
U.S. Dept. of Energy and the ARB Field Study**

Gasoline Grade		California Consumer Grade Selection (Percent of Statewide Totals)[1]			
	U.S. DOE	The Bay Area	Los Angeles	Lake Tahoe	Overall
Premium	13	16	15	9	13
Mid-Grade	15	12	16	13	13
Regular	72	72	69	78	75
Total	100	100	100	100	100

[1] Totals may not add-up to 100 percent due to rounding.

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[4] U.S. Department of Energy, Energy Information Administration, "Petroleum Marketing Monthly," August and September 2001 issues.

V. FIELD STUDY COMMINGLING RESULTS

This chapter discusses the RVP impacts observed in the field study from mixing different types of fuels (i.e., non-ethanol, ethanol, etc). The first part of the chapter discusses each of the various fuel mixing combinations observed. Because a different commingling impact can be expected with a specific fuel blending combination (ie, mixing MTBE fuel with MTBE fuel versus mixing ethanol blended fuel with non-oxygenated fuel), the associated changes in RVP due to each fuel mixing scenario are also discussed. Based on this, the commingling impacts for each region (based on the individual fuel mixing scenarios), as well as for the state as a whole, are then estimated.

A. Field Observations of Commingling Impacts

Based on staff's observations, there were five potential fuel-mixing combinations that occurred during the field study. These fuel-mixing combinations included:

- Mixing non-ethanol-blended gasolines.
- Mixing ethanol-blended gasolines.
- Dispensing ethanol-blended gasoline into non-ethanol-blended gasoline
- Dispensing non-ethanol-blended gasoline into already commingled gasoline
- Dispensing ethanol-blended gasoline into already commingled gasoline
- Dispensing non-ethanol-blended gasoline into ethanol-blended gasoline.

With the exception of the last combination listed above, the RVP characteristics of each of these fuel-mixing combinations are discussed below. The mixing of non-ethanol blends into ethanol blends is not further discussed because there were not sufficient data collected to perform an analysis for this fuel-mixing combination. However, staff has estimated a commingling impact from this fuel-mixing combination based on available literature, and it is presented in Table V-6 at the end of this chapter. The fuel-mixing combinations identified above are inclusive of all the documented fuelings regardless of fuel grade purchased and brand loyalty.

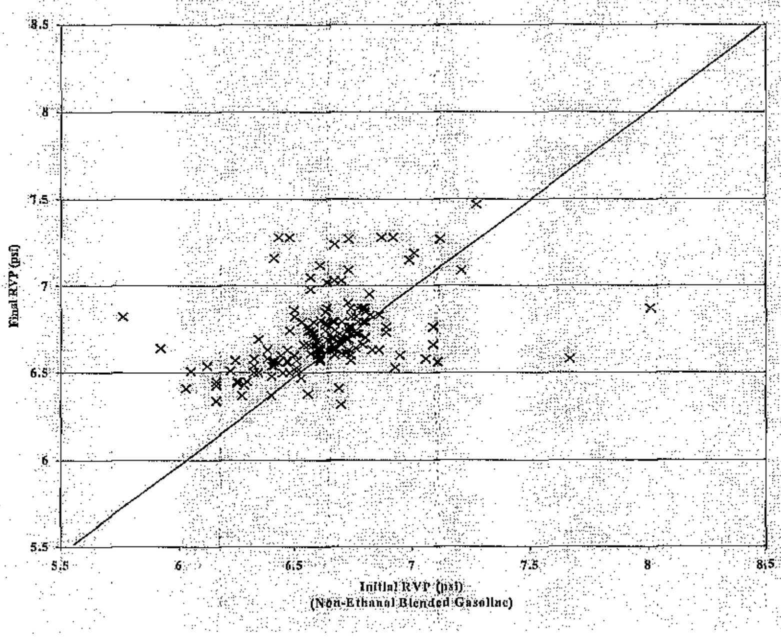
When evaluating the field data based on the above classifications, it is important to note that "non-ethanol blends" refer to either non-oxygenated or MTBE produced gasoline. "Commingled gasoline" refers to gasoline that contains at least 0.5 volume percent ethanol, but less than 5 volume percent ethanol, regardless of the MTBE content.

1. Mixing Non-Ethanol-Blended Gasolines

In general, the mixing of non-ethanol blended gasoline does not result in a commingling impact or unexpected increase in RVP of the resulting mixture. Because of this, both the federal RFG and the CaRFG3 regulations allow for the mixing of non-ethanol blends in the distribution system as long as any minimum oxygen content requirement is satisfied. During the period of time the field study was conducted, nearly 90 percent of gasolines supplied in California were non-ethanol blends. Because of this, most of the fuel samples obtained in the field study were non-ethanol blends.

In the field study, staff collected fuel samples from 165 fuelings involving non-ethanol blends. These data are shown in Figure V-1. The data are graphed according to the initial and final fuel tank RVP. In using this methodology, staff was able to graphically illustrate changes in the final fuel tank RVP as compared to the initial fuel tank RVP. The solid line in Figure V-1 represents no change in fuel tank RVP due to fueling.

Figure V-1. RVP Characteristics of Mixing Non-Ethanol Blended Gasolines

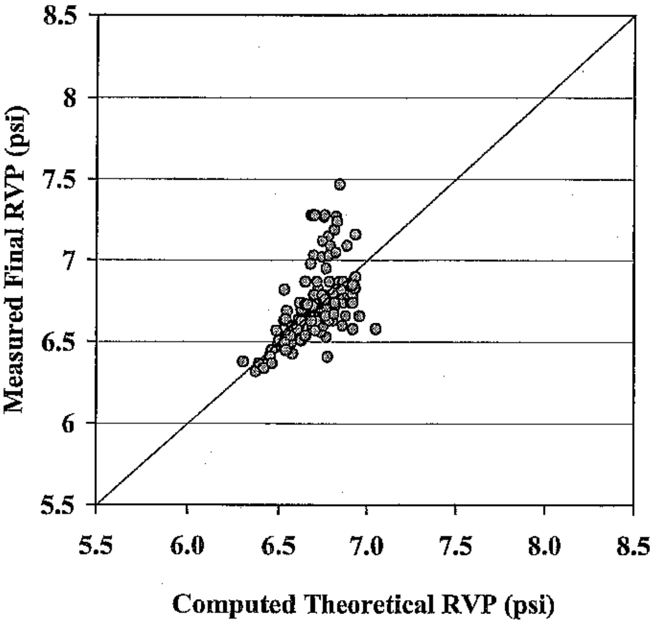


As can be seen in Figure V-1, on average small increases between the initial and final fuel tank RVP were observed in the field study data. The changes that were observed were likely the result of dispensing a higher RVP fuel into a "weathered" fuel in the vehicle fuel tank. Fuel weathering is a result of lighter, more volatile components evaporating from the fuel tank during the period between fuelings. This evaporative loss of volatile components results in a natural reduction in the fuel tank RVP with time. As a result, when higher RVP fuel is blended with a lower RVP weathered fuel in the vehicle fuel tank during fueling, the RVP of the existing fuel in the fuel tank increases linearly towards that of the dispensed fuel.

In light of this mixing of two fuels with different RVPs, staff was interested in evaluating how the final measured fuel tank RVP compared with what would be predicted due to the linear RVP response of mixing two dissimilar RVP fuels. To perform this evaluation, staff determined the initial tank volume prior to fueling as indicated by the fuel gauge, considering that the vehicle tank included a five percent tank 'heel' defined as the unusable volume of fuel at the very bottom of a vehicle fuel tank[5]. In addition, staff also assumed that five percent of the useable fuel remains even for a vehicle recorded as an empty tank in the field data. Using these assumptions and the volumetric amount of fuel dispensed, staff then calculated the theoretical final fuel tank RVP due solely to the linear contribution of each fuel's RVP in the final fuel. This value will be referred to as the "theoretical RVP". A more detailed explanation of staff's methodology is provided in Appendix F.

The results of staff's analysis are presented in Figure V-2. The data are graphed according to the measured final fuel tank RVP and the theoretical RVP. Staff believes that presenting the data in this manner is a better indicator of commingling impacts. This is because the theoretical RVP is independent of commingling impacts. Therefore, an increase in the measured final fuel tank RVP in relation to the theoretical RVP should represent the commingling impact. The solid line in Figure V-2 represents no change in fuel tank RVP due to commingling. As can be seen in Figure V-2, most of the data points are clustered along the solid line, indicating that, as expected, commingling does not occur when non-ethanol-blended gasolines are mixed.

Figure V-2. RVP Characteristics of Mixing Two Non-Ethanol-Blended Gasolines



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[5] Support for consideration of a five percent tank heel is provided in the report, "A Vehicle Fuel Tank Flush Effectiveness Evaluation Program," Lee J. Grant, Southwest Research Institute, August 20, 2001. A copy is provided in Appendix E.

A descriptive statistical analysis of the complete set of fuel characteristics including mean, median, range, minimum, maximum, and sample count derived from these fuelings is presented in Appendix G.

Table V-1 summarizes the average measured RVP characteristics of mixing non-ethanol-blended gasoline in vehicle fuel tanks, as well as the average theoretical RVP calculated. As can be clearly seen, when non-ethanol fuels are mixed, the final measured RVP in the vehicle fuel tank is nearly identical to the theoretical RVP calculated, both of which are also nearly identical to that of the average fuel being dispensed into the vehicle fuel tank.

In Table V-1, the fact that the average dispensed fuel RVP (6.74 psi) is nearly identical to the theoretical RVP (6.71 psi) is important. Since the theoretical RVP of mixing two hydrocarbon fuels should be a linear function of the two fuels RVP and their relative volume proportions in the blend (i.e., initial and dispensed), a resultant RVP very close to one of the fuels RVP is indicative of a very high proportion of that fuel in the final mix. In the case of Table V-1, a significantly high percentage of dispensed fuel in the fuel tank. This is indicative of very low initial fuel tank levels, and is consistent with the data presented in Chapter IV which showed a large majority of the fuelings occurred at very low initial fuel tank levels, generally less than a quarter tank. As a result, the dispensed fuel RVP dominates the volume-weighted RVP, particularly for fillup fuelings.

Table V-1:
Average RVP Characteristics from the Mixing of Non-Ethanol-Blended Gasolines[1]

Fuel Sample	RVP (psi)
Initial Measured	6.63
Dispensed	6.74
Theoretical	6.71
Final Measured	6.72

[1] Based on 160 observed fuelings.

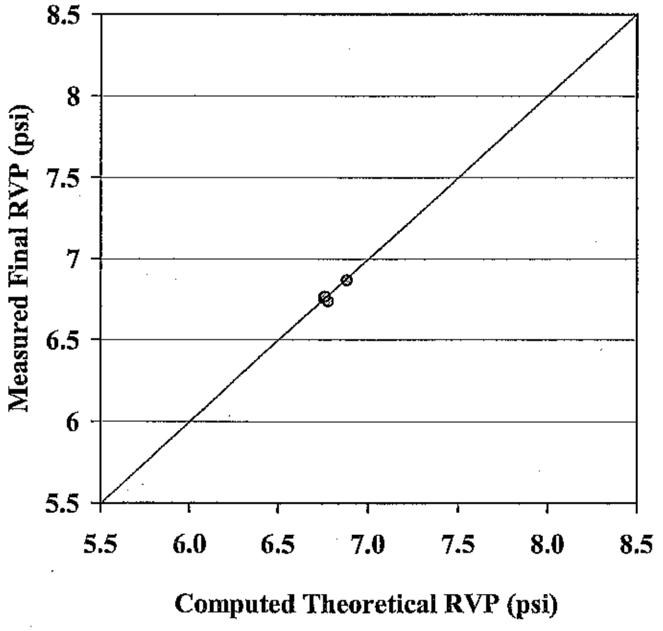
Finally, although staff observed 165 fuelings in this category, the average values presented in Table V-1 are based on 160 of those events. Data from five fuelings were not included in this analysis due to the extremely low RVP of the dispensed fuels. The minimum RVP specification incorporated into the Phase II federal RFG complex model is 6.4 psi (40 Code of Federal Regulations[CFR], section 80.45). The RVP of the gasoline dispensed in these five events was below this minimum RVP specification, and therefore, did not meet the minimum requirements for federal RFG. Since federal RFG areas will represent 80 percent of the California gasoline market later this year, staff does not believe it is appropriate to include those fuels in their statewide analysis as these fuels are unlikely to be widely distributed in California.

2. Mixing Ethanol-Blended Gasolines

Similar to non-ethanol-blended gasolines, the mixing of ethanol-blended gasolines does not result in a commingling impact or unexpected increase in RVP. This is because the two ethanol fuels have already experienced an increase in their RVPs due to the addition of ethanol during their production. Mixing them together will not result in any further increases in their RVP. As a result, when two ethanol fuels are mixed, staff expected that they should experience the same linear RVP response as mixing non-ethanol gasolines, and that the measured final RVP should be similar to the theoretical RVP.

In the field study, staff collected only four fuel samples involving the mixing of ethanol blended gasolines. These data are presented in Figure V-3. The data are graphed according to the measured final fuel tank RVP and the theoretical RVP. The solid line in Figure V-3 represents no change in fuel tank RVP due to commingling. As can be seen, most of the data points fall along the solid line, indicating that, as expected, commingling does not occur when ethanol-blended gasolines are mixed.

Figure V-3. RVP Characteristics of Mixing Two Ethanol-Blended Gasolines



A descriptive statistical analysis of the complete set of fuel characteristics including mean, median, range, minimum, maximum, and sample count derived from these fuelings is presented in Appendix H.

Table V-2 summarizes the average measured RVP characteristics of mixing ethanol-blended gasoline in vehicle fuel tanks, as well as the average theoretical RVP calculated. As can be clearly seen, when ethanol-blended fuels are mixed, the final measured RVP in the vehicle fuel tank is nearly identical to the theoretical RVP calculated.

Table V-2:
Average RVP Characteristics from the Mixing of Ethanol-Blended Gasolines[1]

Fuel Sample	RVP (psi)
Initial Measured	6.76
Dispensed	6.84
Theoretical	6.79
Final Measured	6.79

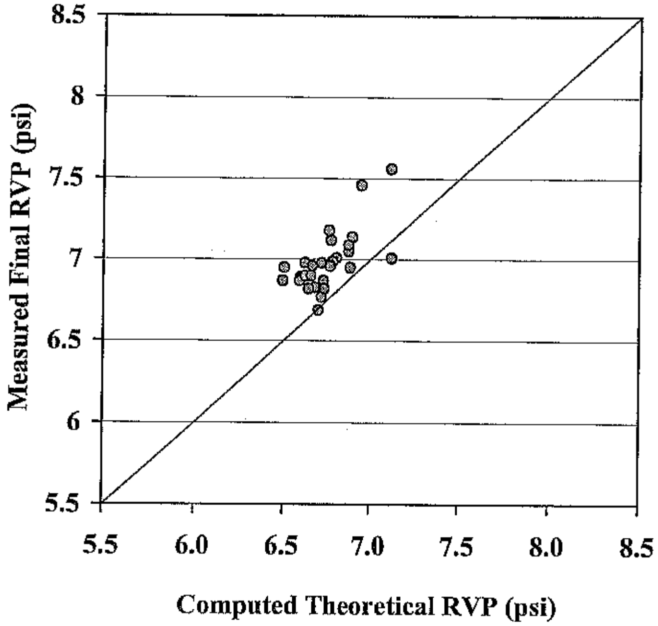
[1] Based on 4 observed fuelings.

3. Dispensing Ethanol-Blended Gasoline into Non-Ethanol-Blended Gasoline

As expected, the dispensing of ethanol blended gasoline into non-ethanol blended gasoline resulted in an overall increase in the RVP of the fuel originally in the fuel tank. Staff believes that this increase in RVP occurs as a result of two phenomena. First, as seen previously in the mixing of non-ethanol fuels, adding higher RVP fuel to weathered fuel in a vehicle fuel tank raises the RVP of the weathered fuel. In addition, the commingling of ethanol with the original fuel in the tank also increases the RVP of that fuel. These two mechanisms combined result in the overall measured RVP increase in the fuel originally in the tank prior to fueling.

In the field study, staff collected fuel samples from 29 fuelings involving dispensing ethanol-blended gasoline into non-ethanol blends. These data are shown in Figure V-4. The data are graphed according to the measured final fuel tank RVP and the theoretical RVP. The solid line in Figure V-4 represents no change in fuel tank RVP due to commingling. As can be seen, most of the data points are above the solid line, indicating there is an increase in RVP between the theoretical and final measured fuel tank RVP.

Figure V-4. RVP Characteristics of Dispensing Ethanol-Blended into Non-Ethanol-Blended Gasoline



A descriptive statistical analysis of the complete set of fuel characteristics including mean, median, range, minimum, maximum, and sample count, derived from these fuelings is presented in Appendix I.

Table V-3 shows the average initial and final fuel tank RVP, the average dispensed fuel RVP, as well as the average theoretical RVP calculated. As can be seen, the data show that there is an RVP increase due to commingling of about 0.23 psi between the average theoretical and final fuel tank RVP.

Table V-3:
Average RVP Characteristics from Dispensing Ethanol-Blended Gasoline into Non-Ethanol-Blended Gasoline[1]

Fuel Sample	RVP (psi)
Initial Measured	6.48
Dispensed	6.84
Theoretical	6.75
Final Measured	6.98

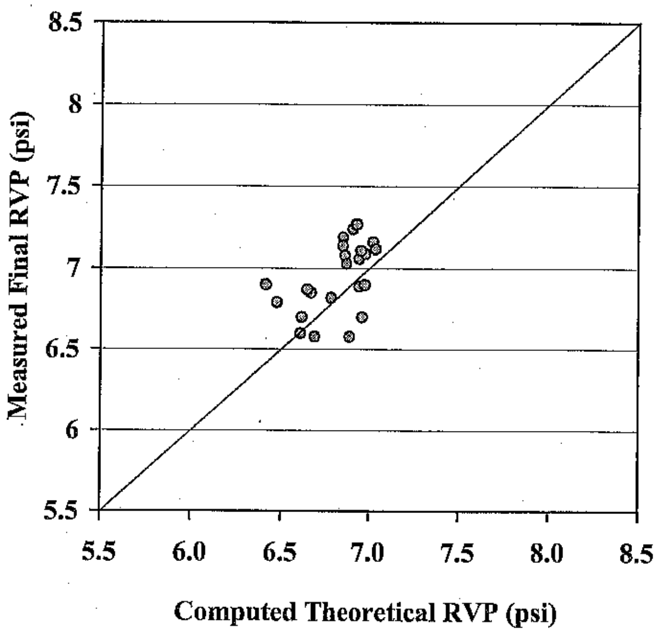
[1] Based on 29 observed fuelings.

4. Dispensing Non-Ethanol-Blended Gasoline into Already Commingled Gasoline

Staff's original expectation of dispensing non-ethanol-blended gasoline into already commingled gasoline was that an overall increase in the RVP of the fuel being dispensed into the tank would be observed. This is based on the anticipated commingling of the dispensed fuel by the ethanol present in the already commingled fuel in the vehicle fuel tank.

In the field study, staff collected fuel samples from 25 fuelings involving dispensing non-ethanol-blended gasoline into already commingled fuel. These data are shown in Figure V-5. The data are graphed according to the measured final fuel tank RVP and the theoretical RVP. The solid line in Figure V-5 represents no change in fuel tank RVP due to commingling. As can be seen, most of the data points are above the solid line, indicating there is an increase in RVP between the theoretical and final measured fuel tank RVP.

Figure V-5. RVP Characteristics of Dispensing Non-Ethanol Blended Gasoline into Already Commingled Gasoline



A descriptive statistical analysis of the complete set of fuel characteristics including mean, median, range, minimum, maximum, and sample count, derived from these fuelings is presented in Appendix J.

As can be seen in Figure V-5, similar to the previous fuel-blending scenario discussed, the results of this fuel-blending combination generally result in an increase in the measured final fuel tank RVP as compared to that predicted according to the theoretical RVP.

Table V-4 shows the average initial and final fuel tank RVP, the average dispensed fuel RVP, as well as the average theoretical RVP calculated. As can be seen, the data show that there is an RVP increase due to commingling of about 0.12 psi between the average theoretical and final fuel tank RVP.

Table V-4:
Average RVP Characteristics from Dispensing Non-Ethanol Blended Gasoline into Commingled Gasoline[1]

Fuel Sample	RVP (psi)
Initial Measured	6.93
Dispensed	6.77
Theoretical	6.85
Final Measured	6.97

[1] Based on 21 fuelings.

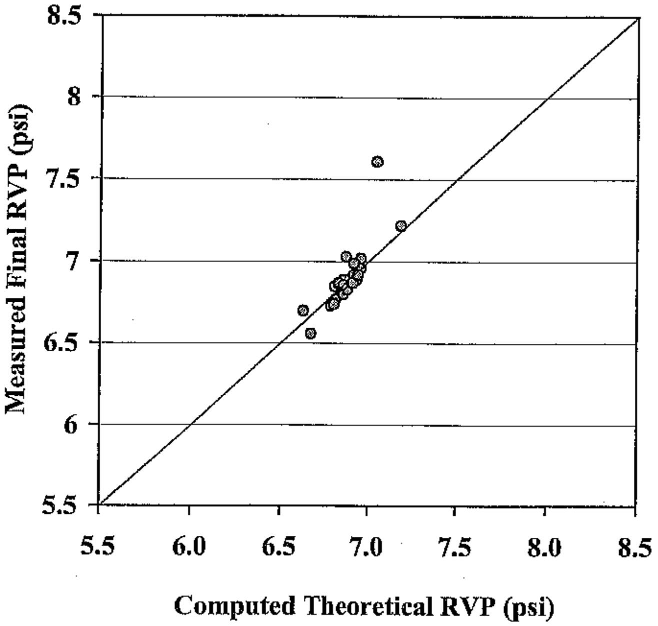
Although staff observed 24 fuelings in this category, the average values presented are based on 21 of those events. Data from three fuelings were not included in this analysis due to the extremely low RVP of the dispensed fuels. The minimum RVP specification incorporated into the Phase II federal RFG complex model is 6.4 psi (40,CFR, 80.45). The RVP of the gasoline dispensed in these four events was below this minimum RVP specification, and therefore, could not be used in federal RFG areas, which will represent 80 percent of the California market later this year.

5. Dispensing Ethanol-Blended Gasoline into Already Commingled Gasoline

Staff did not expect that the mixing of an ethanol-blended gasoline into an already commingled gasoline would result in a significant increase in RVP. This is because a commingled fuel has already experienced an RVP increase and staff believed that the mixing of an ethanol blended gasoline into an already commingled gasoline would result in little, if any, RVP increase. In addition, since as little as two volume percent ethanol will effect the full commingling impact, it was expected that additional ethanol would not cause any RVP increases.

In the field study, staff collected fuel samples from 25 fuelings where a mixing of an ethanol-blended gasoline into an already commingled gasoline was observed. These data are shown in Figure V-6. The data are graphed according to the measured final fuel tank RVP and the theoretical RVP. The solid line in Figure V-6 represents no change in fuel tank RVP due to commingling. As can be seen in Figure V-6, in general there were only minor differences in the final measured fuel tank RVP as compared to the theoretical RVP, indicating very small commingling impacts were observed.

Figure V-6. RVP Characteristics of Dispensing Ethanol-Blended Gasoline into Already Commingled Gasoline



A descriptive statistical analysis of the complete set of fuel characteristics including mean, median, range, minimum, maximum, and sample count, derived from these fuelings is presented in Appendix K.

Table V-5 shows the average initial and final fuel tank RVP, the average dispensed fuel RVP, as well as the average theoretical RVP calculated. As can be seen, the data show that there is an RVP increase of about 0.03 psi between the average theoretical and final fuel tank RVP.

Table V-5:
Average RVP Characteristics from Dispensing Ethanol-Blended Gasoline into Commingled Gasoline[1]

Fuel Sample	RVP (psi)
Initial Measured	6.90
Dispensed	6.86
Theoretical	6.88
Final Measured	6.91

[1] Based on 24 Fuelings

Although staff observed 25 fuelings in this category, the average values presented are based on 24 of those events. Data from one fueling event were not included in this analysis due a lack of confidence in the associated data. Data for this event indicated a 1977 Dodge Van with 7/8 initial fuel gage level, initial RVP of 7.56 psi, and an initial ethanol content of 2 percent, is then filled with 12.5 gallons of a dispensed fuel with an RVP of 6.75 psi and an ethanol content of 6 percent. The final fuel tank RVP was 8.2 psi. Due to the unconventional fuel characteristics in response to this vehicle's fueling, data associated with this event were excluded from the analysis for which the results are presented in Table V-5.

B. Overall Findings of Field Observations

Based on staff's above analysis, staff estimated the anticipated commingling impact on the statewide gasoline pool, as well as for the gasoline pools in each of the three areas. To do this, staff used the commingling impact expected for each of the previously discussed fuel blending scenarios, collectively shown in Table V-6.

Table V-6:
Commingling Impacts for Various Fuel Blending Scenarios

Fuel Mixing Scenario	Commingling Impact (ΔRVP, psi)
Mixing non-ethanol-blended gasolines	-0.01
Mixing ethanol-blended gasolines	0.00
Dispensing ethanol blends into non-ethanol blends	0.23
Dispensing non-ethanol blends into ethanol blends	0.37[1]
Dispensing non-ethanol blends into already commingled gasoline	0.12
Dispensing ethanol blends into already commingled gasoline	0.03

[1] This fuel mixing scenario was not addressed in the previous discussion since sufficient data were not collected in the field study to quantify this value. However, staff estimated this impact using data contained in Figure 3 of "Addition of Nonethanol Gasoline to E10 – Effect on Volatility", as contained in Appendix L.

To estimate the overall anticipated statewide commingling impact, staff first used the consumer loyalty information collected in each area, as shown in Figure IV-1. In their analysis, staff assumed that brand loyal consumers were represented by "Mixing of non-ethanol blended gasolines" and "Mixing of ethanol-blended gasolines", which results in no commingling impacts.

Staff computed the anticipated statewide commingling impacts, summarized in Table V-8, as a weighted average of the following factors:

- The regional gasoline consumption[6] fraction as calculated in Table V-7 below. This fraction was used as a weighting factor for each region's commingling contribution.

Table V-7:
1998 Gasoline Consumption by Region[1]

Region	1998 Gasoline Consumption (1,000 gallons)	Regional Gasoline Consumption Fraction
Lake Tahoe	173,999	2%
The Bay Area	3,101,350	33%
Los Angeles	6,074,673	65%
Total	**9,350,023**	**100%**

[1] Source: California Energy Commission, Fuels Office, http://www.energy.ca.gov/fuels/gasoline_stations/index.html

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[6] For staff's analysis, each area was defined as the air basin in which the field sampling occurred, and the fuel consumption was based on the 1998 fuel consumption for each county comprising the respective air basins.

- An average RVP increase of 0.188 psi from the last four fuel mixing scenarios from Table V-6, assuming that non-loyal consumers were equally represented by the last four scenarios (i.e., 25 percent of consumers saw an RVP increase of 0.23 psi, 25 percent of 0.32 psi, etc.). In addition, staff assumed that this factor is the same across regions.

- The percentage of non-loyal consumers from Figure IV-1. As can be seen in Figure IV-1, the percentages of loyal and non-loyal consumer observed do not add up to 100 percent since a small fraction of participants responded "don't know" when asked whether the current gasoline bought was the same as their last purchase. To account for the contribution from the "don't know" group in the commingling analysis, staff included this group into non-loyal consumers. Using this methodology, the corresponding non-loyal consumer figures in Lake Tahoe, the Bay Area, and Los Angeles areas are 69, 42, and 38 percent, respectively.

Staff estimated each region commingling contribution as a product of the above three factors, as shown in Table V-8. Although the Lake Tahoe region shows a much higher non-loyal consumer percentage, the gasoline consumption in the region is the least among the three regions surveyed. As a result, its contribution to the overall statewide commingling impacts is relatively small (only a 0.003 psi RVP increase). In contrast, the Los Angeles region yields the highest contribution, 0.046 psi, followed by the Bay Area, 0.026 psi. The estimated statewide commingling impact, as the sum of the three regions' RVP increase, is approximately 0.07 psi.

Table V-8:
Statewide Commingling Impacts
The 2001 ARB Field Study

Region	Regional Gasoline Consumption Fraction	Ave RVP Increase (psi)	Non-Loyal Consumer Fraction	Regional Commingling Contribution (psi)[1]
Lake Tahoe	0.02	0.188	0.69	0.003
The Bay Area	0.33	0.188	0.42	0.026
Los Angeles	0.65	0.188	0.38	0.046
Total	1.00	Statewide Average		0.07

[1] The sum of regional commingling contributions may be different from the 'Statewide Average' figure due to rounding.

While staff believes that their assessment has provided a reasonable estimation of the commingling impact of mixing non-ethanol fuel into already commingled fuel, it highlights the variability of commingling after the initial commingling event has occurred. This is because there are a significant number of variables that will influence the commingling impact, including the ethanol content of the commingled fuel, the number of subsequent fuelings, and the amount of fuel present prior to fueling. Staff believes that a more accurate estimation of the commingling impacts of mixing these two fuels can be achieved through the use of statistical modeling.

VI. SIMULATION MODELING OF COMMINGLING IMPACTS

In addition to documenting actual impacts of commingling on individual vehicle fuel tanks as observed in the field study, a simulation model was used to estimate potential statewide commingling impacts.

A. Introduction

Using statistical and mathematical approaches, a computer simulation model (model) can simulate complex consumer fuel purchasing decisions under a variety of different sets of conditions or scenarios. In the case of commingling, the model would use input data from assumed conditions that may be prevalent in the future and from field survey data of consumer fueling habits.

This is useful for several reasons. First and foremost, it allows a commingling impact analysis to proceed even though some key market factors that may affect the results are unobserved. In the case of CaRFG3, these factors include ethanol market share, consumers purchase propensity toward ethanol-blended fuel, and the properties of future gasoline blends. They are unknown since the use of ethanol as an oxygenate on a level comparable to MTBE has not yet occurred. In general, to arrive at meaningful results, reasonable assumptions concerning these factors are necessary.

Consumer fueling habits also play an integral role in commingling analysis. The type and volume of dispensed fuel as well as remaining fuel in a vehicle fuel tank prior to fueling influence the RVP of a mixed fuel, and, hence, the commingling impact. As an example, if consumers always purchased fuel when registering nearly an empty tank, the volume of remaining fuel would be nearly negligible, greatly minimizing potential commingling impacts, regardless of the type and volume of fuel being dispensed in each fueling event.

Laboratory analysis of a fuel tank RVP prior to fueling helps shed some light on a consumer's fueling history, e.g., if they had dispensed ethanol-blended fuel in the past. However, the laboratory testing can not establish sequential fuelings that ultimately led to a fuel's measured RVP. In the field, staff recorded only two fuelings—the current and previous. Because of the role consumer fueling habits play in commingling, and the difficulties in using laboratory analysis to determine the specifics of previous fuelings, a simulation model is indispensable. The model is capable of simulating a long sequence of fuelings from a large number of consumers who on average behave similarly to the consumers observed in field study.

All things considered, commingling analysis is complex. So long as the sampled consumers are representative of the California consumer population, the simulation results can be generalized to approximate statewide commingling impacts.

B. Simulation Model

Staff used a simulation model that was developed by David M. Rocke, Ph.D., University of California, Davis (UCD), pursuant to an ARB contract, and made available to the public in 1999. A copy of the FORTRAN source code is attached (Appendix M), including a user's manual.

Using a statistical and mathematical approach, the model makes use of random sample data, expands the scope of the analysis that may not have been observed in the actual data by randomly drawing new observations based on the observed parameters of important variables (e.g., mean and standard deviation of initial fuel tank levels), and, at the end, summarizes the results. In the process, it also takes into account variation and uncertainty from which a valid inference can be drawn.

In evaluating commingling impacts, staff began with observations of consumer fueling patterns, as well as RVP changes in vehicle fuel tanks, from a random sample of the California motorist population. Staff derived key parameters, means and standard deviations, from the sample that is assumed governed by certain probability distributions where variation and uncertainty are considered. The model takes this information, and simulates consumer fuel buying habits by allowing each individual to be randomly different from the others; yet, on average, they should mimic the observed random sample. This randomness is vital as it provides a mean for staff to generalize the results for the entire population to reach a valid conclusion.

C. Methodology of Simulation Analysis

The field study showed that consumers behave differently across geographic regions in the state. For example, consumers in Los Angeles showed higher brand loyalty, refueled when less fuel remained in the vehicle tank, but were less likely to fillup than consumers in the Bay Area or Lake Tahoe (Figure IV-3). Based on this information, consumers from each region were analyzed separately to determine commingling impacts.

1. Loyal Consumers

A key assumption in staff's modeling work was that fueling by those consumers that used the same brand of gasoline as their previous fuel purchase ("loyal" consumers) resulted in no or negligible commingling occurring in their vehicle tanks.

The basis for this assumption is that, a fuel station that sells a certain brand of gasoline is unlikely to sell two types of fuel simultaneously (i.e., non-ethanol and ethanol-blended gasolines). As a result, loyal consumers get the same fuel type for every fueling, so the mixing of non-ethanol and ethanol-blended gasolines, on which the commingling analysis is based, will not occur. Ideally, fuel-type loyalty data should be used instead of brand loyalty to assess the commingling impacts. However, in the absence of fuel-type loyalty data, brand loyalty data are the best surrogate data. More discussion on brand loyalty data is provided in the next section.

2. Non-Loyal Consumers

Staff then used the UCD model to simulate a wide range of scenarios of commingling impacts for "non-loyal" consumers in each region. To develop a statewide average of commingling impacts, the contribution from non-loyal consumers toward commingling in each region was weighted by the corresponding proportion of non-loyal consumers and gasoline consumption, as described in Chapter IV.

D. Input Data & Assumptions

As previously described, the actual impacts of commingling on emissions depend on many variables that are input to the model. The input data are bifurcated according to future ethanol market conditions and current consumer behavior patterns that are expected to hold in the future.

1. Future Ethanol Market Conditions

Uncertainty involved in dealing with these data necessitates staff to assume various scenarios that are expected to cover a wide range of potential commingling impacts and to bracket the likely range of commingling impacts. In selecting values to input into these scenarios, staff used the best data available, including recent reports, and stakeholder consultation.

Ethanol Market Share: Under a waiver scenario, staff assumed that the future California ethanol market share would vary from 25 percent to 65 percent of the gasoline market. This is consistent with that documented in a report prepared for the U.S. EPA by MathPro Inc., titled "Analysis Of The Production Of CaRFG3 With And Without An Oxygen Waiver," (2001). Staff further assumed that this assumption holds across gasoline grades. That is, ethanol market share is the same for all grades. By assuming a constant ethanol market share across grades, staff has attempted to account for the commingling impacts associated with potential grade switching when information on grade loyalty is currently unavailable.

Ethanol Blending Concentrations: After consulting with gasoline producers, staff assumed that gasoline produced with either 6 volume percent or 7.7 volume percent of ethanol are the likely future California fuel blends. As such, staff utilizes these fuels in their analysis. Like ethanol market share, these blends also apply to all grades due to fuel distribution system constraints (i.e., fuel quality specifications set by a common carrier pipeline company). Consequently, grade switching within the same brand would not lead to commingling. This assumption seems reasonable, in part, because most grade switching is expected to occur within the same brand, and both regular and premium grade of gasolines are expected to contain the same amount of ethanol for a given gasoline brand. Moreover, consumer survey data show grade market share remains constant over time, except during short periods of gasoline price spikes.

Based on average RVP of the dispensed fuels from the field study, staff assumed 6.71 psi base RVP for non-oxygenated fuel and 5.74 psi for ethanol fuel (i.e., 6.84 psi RVP from the average 5.6 volume percent ethanol-blended gasolines observed in the field minus a 1.1 psi expected RVP increase from ethanol blending).

Fuel Type Switching Patterns: Because the pattern in which ethanol and non-ethanol gasolines are dispensed into a vehicle has a significant impact on commingling, the simulation model must generate the non-loyal consumers fuel type switching patterns to produce an estimate of the commingling impacts. First, the model randomly assigns each consumer with a fixed "ethanol purchase propensity value". Appendix N describes this concept in more detail. Using this value, the model then randomly generates a sequence of fuel switching patterns.

For example, consider two non-loyal consumers with a 50 percent ethanol purchase propensity. In this case, the two consumers are equally likely to switch between non-ethanol-blended and ethanol-blended gasolines for each fueling event. For ten fueling events, the first consumer would cause maximum commingling impacts if they alternately switch fuel type. If "N" and "E" denote fueling non-ethanol and ethanol-blended gasolines, respectively, NENENENENE or ENENENENEN represents the above sequence of ten fuelings. All else being equal (e.g., remaining fuel in a vehicle fuel tank prior to fueling and amount of fuel dispensed), contrast this with the minimal commingling impacts from the second consumer who switches fuel with the following sequence: NNNNNEEEEE or EEEEENNNNN. In the latter case, the first five fuelings are of one type followed by the next five of another type, so fueling number six and beyond are where the commingling impacts should be considered. However, if at the7th fueling a consumer rolled in with an empty tank, the commingling impacts would theoretically be limited to the 6th fueling only.

2. Consumer Fueling Habits

Table VI-1 below summarizes non-loyal consumer fueling habits by region. These fueling habits are more fully discussed below.

Brand Loyalty: The regional non-loyal consumer fractions from Figure IV-1, including the 'don't know' group, are again shown in Table VI-1. These figures and the regional gasoline consumption (Table V-7) were used as weighting factors to estimate statewide commingling impacts.

Table VI-1 Non-Loyal Consumers* Fueling Information By Region

The 2001 ARB Field Study

Variable	Lake Tahoe	SF Bay Area	Los Angeles
Non-Loyal Consumer (%)	69	42	38
Ave. Initial Fuel Tank Levels (as a fraction of usable tank capacity)	0.23	0.2	0.18
Fillup (%)	52	58	24
Ave. Fuel Amount Purchased for Non-Fillup (as a fraction of usable tank capacity)	0.35	0.32	0.37

*Including "don't know" group

Initial Fuel Tank Level: According to the field study, the majority of consumers (about 80 percent) fuel when there is ¼ tank of gasoline or less remaining in their tanks, with more than 40 percent registering nearly an empty tank. In evaluating the data, the mean initial fuel tank level for non-loyal consumers is comparable to the overall sample's mean. On average, consumers in Los Angeles have lower initial fuel tank levels than consumers in the Bay Area or Lake Tahoe, as shown in Table VI-1.

In practice, as described in the previous chapter, although fuel gauge may register empty, staff believes that some fuel still remains in the tank. Staff assumed about five percent tank capacity of usable fuel for initial fuel tanks recorded as empty ("E") in the field study. The mean tank levels presented in Table VI-1 were computed based on this assumption.

In addition, staff assumed a five-percent tank "heel," regardless of initial fuel tank levels. This assumption is supported by data from the Southwest Research Institute (Appendix E). As a result, the simulation model also assumes a five-percent or one-gallon tank heel, based on an average 20-gallon tank capacity. This 20-gallon tank capacity is derived from weighted average tank capacity of passenger car, estimated to be16-gallon, and light-duty trucks estimated to be 24-gallon where both vehicle classes are about equally represented in the sample.

Amount Of Fuel Purchased: As can be seen in Table VI-1, the data collected on non-loyal consumers follow similar fillup trends as the overall consumers observed in Figure IV-3. For example, non-loyal consumers in Los Angeles are the least likely to fillup among non-loyal consumers in the three regions. Also, the data for the average amount of fuel purchased for non-fillup events are comparable among the three regions.

3. Summary of Input Data

From the mean and standard deviation of each variable in Table VI-2, the corresponding input parameters (i.e., beta distribution) were derived for the commingling simulation analysis. Table VI-2 summarizes the input data and assumptions for the model. The upper portion of the table (above the dashed line) lists the input assumptions for the future ethanol market conditions while the lower portion identifies the field survey information. Unlike the future ethanol market conditions, the field survey information is assumed to remain constant for each different scenario analyzed (this is further explained in Chapter VII.). For example, premium consumers would fillup with the same frequency, regardless of whether ethanol market share was 25 percent or 50 percent.

Table VI-2 Input Data & Assumptions
For Simulation Model

Variables		Lake Tahoe	SF Bay Area	Los Angeles
Ethanol Content (vol%)		6 or 7.7	6 or 7.7	6 or 7.7
Base RVP (psi)	- Non-oxygenated	6.71	6.71	6.71
	- Oxygenated	5.74	5.74	5.74
Ethanol Market Share (%)		25 - 65	25 - 65	25 - 65
Distribution of EtOH Purchase Propensity ($\alpha+\beta$)*		1, 2, or 5	1, 2, or 5	1, 2, or 5
Initial Fuel Tank Level (mean, fraction of tank cap.)		0.23	0.2	0.18
Distribution of Initial Fuel tank Level ($\alpha+\beta$)		3.3	4.5	2.6
Fillup Frequency (mean)		0.52	0.58	0.24
Distribution of Fillup Frequency ($\alpha+\beta$)		6.7	3.6	4.7
Fuel Purchased for Non-Fillup (mean, fraction of tank cap.)		0.42	0.36	0.42
Dist. of Fraction Amount Purchased for Non-Fillup ($\alpha+\beta$)		2.8	4.6	2.5

*The 2001 ARB field study did not specifically elicit cunsumers purchase propensity toward ethanol fuel.

The figures are for different assumptions (1 = less conservative, 2 = base case, and 5 = more conservative scenarios).

VII. SIMULATION RESULTS

This chapter describes the results of staff's use of the UCD simulation model to access the potential impacts of CaRFG3 commingling.

A. Statewide Potential Commingling Impacts

Using the UCD simulation model and assumed future ethanol market conditions (as discussed in Chapter VI), as well as consumer fueling behavior from the field study (as described in Chapter IV) as input, staff simulated a total of 162 fueling scenarios. These included all possible combinations of:

- 3 regions;
- 3 ethanol purchase propensity distributions;
- 9 ethanol market shares from 25 percent to 65 percent in five percent increments, and;
- 2 ethanol blends, 6 volume percent and 7.7 volume percent.

Each scenario represents 5,000 consumers with 500 fuelings per consumer, resulting in the modeling of over 400 million fuelings. The model then computes the average commingling effect for each scenario.

The first set of scenarios (i.e., ethanol purchase propensity based on a beta distribution, with $\alpha + \beta$ equal to 2) is collectively called the base case scenario. Table VII-1 summarizes the results of the base case scenario. The top half (above solid line) of Table VII-1 shows the commingling impacts of using a 6 volume percent ethanol blend while the bottom half shows the impacts of using a 7.7 volume percent blend. The two blends are assumed to have the same base RVP. RVP increases due to commingling are estimated for each region, as shown in Appendix O. These increases are weighted by the corresponding regional non-loyal consumer proportions and gasoline consumptions as described in Chapter VI, and the results are presented in Table VII-1. The last column in Table VII-1 is the total statewide commingling impact as the sum of the three regions weighted-average RVP increases for each ethanol market penetration. For example, if ethanol market share is 25 percent of total gasoline pool, the regional commingling contribution are estimated to be 0.002 psi, 0.020 psi, and 0.033 psi RVP in Lake Tahoe, the Bay Area, and Los Angeles, respectively, for 6 volume percent ethanol blends.

As expected, the anticipated commingling effect increases with ethanol market penetration, and peaks at around 45 percent to 50 percent market share. For the base case scenario, the model estimated average statewide commingling impacts of 0.055-0.069 psi RVP for 6 volume percent ethanol blends and 0.062-0.077si RVP for 7.7 volume percent ethanol blends.

Table VII-1
Estimated Statewide Commingling Impacts For Various Ethanol Blends And Market Shares
Using The 2001 ARB Field Study Input Parameters
Base Case Scenario (Beta Distribution, $\alpha+\beta=2$)
(Draft)

Ethanol Market Share (%)	Ethanol Content (%vol)	Base RVP Non-Oxy Fuel (psi)	Base RVP Ethanol Fuel (psi)	Estimated RVP Increase Due To Commingling By Region (psi)			
				Lake Tahoe*	Bay Area*	Los Angeles*	Statewide
25	6	6.71	5.74	0.002	0.020	0.033	0.055
30	6	6.71	5.74	0.002	0.022	0.037	0.062
35	6	6.71	5.74	0.002	0.022	0.040	0.064
40	6	6.71	5.74	0.002	0.022	0.043	0.067
45	6	6.71	5.74	0.003	0.024	0.041	0.068
50	6	6.71	5.74	0.003	0.024	0.042	0.069
55	6	6.71	5.74	0.002	0.024	0.043	0.069
60	6	6.71	5.74	0.002	0.024	0.039	0.066
65	6	6.71	5.74	0.002	0.022	0.037	0.061
25	7.7	6.71	5.74	0.002	0.022	0.037	0.062
30	7.7	6.71	5.74	0.002	0.025	0.042	0.069
35	7.7	6.71	5.74	0.003	0.025	0.044	0.072
40	7.7	6.71	5.74	0.003	0.025	0.048	0.075
45	7.7	6.71	5.74	0.003	0.027	0.046	0.076
50	7.7	6.71	5.74	0.003	0.027	0.047	0.077
55	7.7	6.71	5.74	0.003	0.026	0.048	0.077
60	7.7	6.71	5.74	0.003	0.026	0.044	0.073
65	7.7	6.71	5.74	0.002	0.025	0.041	0.068

*These figures are calculated from the average RVP increases in each region weighted by the corresponding non-loyal consumer proportions and gasoline consumptions.

B. Sensitivity Analysis

Using the UCD model, staff also performed sensitivity analysis of potential commingling impacts. The sensitivity analysis is related to staff's input assumptions, regarding different ethanol purchase propensities.

The results of this sensitivity analysis are shown in Tables VII-2 and VII-3. Table VII-2 presents a more conservative ($\alpha + \beta=5$) estimate of commingling impacts relative to the base case while Table VII-3 is less conservative ($\alpha + \beta=2$) compared to the base case.

Using the same methodology as in the base case, the statewide commingling impacts were estimated. Again as can be seen in the tables, the largest impacts occur when the ethanol market share is around 45 percent to 50 percent.

Table VII-2

Estimated Statewide Commingling Impacts For Various Ethanol Blends And Market Shares

Using The 2001 ARB Field Study Input Parameters

More Conservative Scenario (Beta Distribution, $\alpha+\beta=5$)

(Draft)

Ethanol Market Share (%)	Ethanol Content (%vol)	Base RVP Non-Oxy Fuel (psi)	Base RVP Ethanol Fuel (psi)	Estimated RVP Increase Due To Commingling By Region (psi)			
				Lake Tahoe*	Bay Area*	Los Angeles*	Statewide
25	6	6.71	5.74	0.003	0.026	0.043	0.072
30	6	6.71	5.74	0.003	0.028	0.046	0.076
35	6	6.71	5.74	0.003	0.029	0.050	0.082
40	6	6.71	5.74	0.003	0.031	0.052	0.086
45	6	6.71	5.74	0.003	0.030	0.054	0.087
50	6	6.71	5.74	0.003	0.030	0.053	0.086
55	6	6.71	5.74	0.003	0.030	0.052	0.084
60	6	6.71	5.74	0.003	0.028	0.050	0.081
65	6	6.71	5.74	0.003	0.026	0.046	0.075
25	7.7	6.71	5.74	0.003	0.029	0.048	0.081
30	7.7	6.71	5.74	0.003	0.031	0.052	0.086
35	7.7	6.71	5.74	0.003	0.032	0.056	0.091
40	7.7	6.71	5.74	0.003	0.034	0.058	0.096
45	7.7	6.71	5.74	0.003	0.034	0.060	0.097
50	7.7	6.71	5.74	0.003	0.033	0.059	0.096
55	7.7	6.71	5.74	0.003	0.033	0.057	0.094
60	7.7	6.71	5.74	0.003	0.031	0.055	0.090
65	7.7	6.71	5.74	0.003	0.029	0.051	0.083

*These figures are calculated from the average RVP increases in each region weighted by the corresponding non-loyal consumer proportions and gasoline consumptions.

Table VII-3
Estimated Statewide Commingling Impacts For Various Ethanol Blends And Market Shares
Using The 2001 ARB Field Study Input Parameters
Less Conservative Scenario (Beta Distribution, $\alpha+\beta=1$)
(Draft)

Ethanol Market Share (%)	Ethanol Content (%vol)	Base RVP Non-Oxy Fuel (psi)	Base RVP Ethanol Fuel (psi)	Estimated RVP Increase Due To Commingling By Region (psi)			
				Lake Tahoe*	Bay Area*	Los Angeles*	Statewide
25	6	6.71	5.74	0.001	0.014	0.023	0.039
30	6	6.71	5.74	0.002	0.017	0.026	0.045
35	6	6.71	5.74	0.002	0.017	0.028	0.047
40	6	6.71	5.74	0.002	0.018	0.032	0.051
45	6	6.71	5.74	0.002	0.017	0.031	0.050
50	6	6.71	5.74	0.002	0.019	0.031	0.052
55	6	6.71	5.74	0.002	0.018	0.031	0.051
60	6	6.71	5.74	0.002	0.017	0.028	0.046
65	6	6.71	5.74	0.002	0.017	0.027	0.046
25	7.7	6.71	5.74	0.002	0.016	0.026	0.043
30	7.7	6.71	5.74	0.002	0.019	0.029	0.050
35	7.7	6.71	5.74	0.002	0.019	0.032	0.053
40	7.7	6.71	5.74	0.002	0.020	0.035	0.057
45	7.7	6.71	5.74	0.002	0.019	0.035	0.056
50	7.7	6.71	5.74	0.002	0.021	0.034	0.058
55	7.7	6.71	5.74	0.002	0.020	0.034	0.056
60	7.7	6.71	5.74	0.002	0.019	0.031	0.052
65	7.7	6.71	5.74	0.002	0.019	0.031	0.051

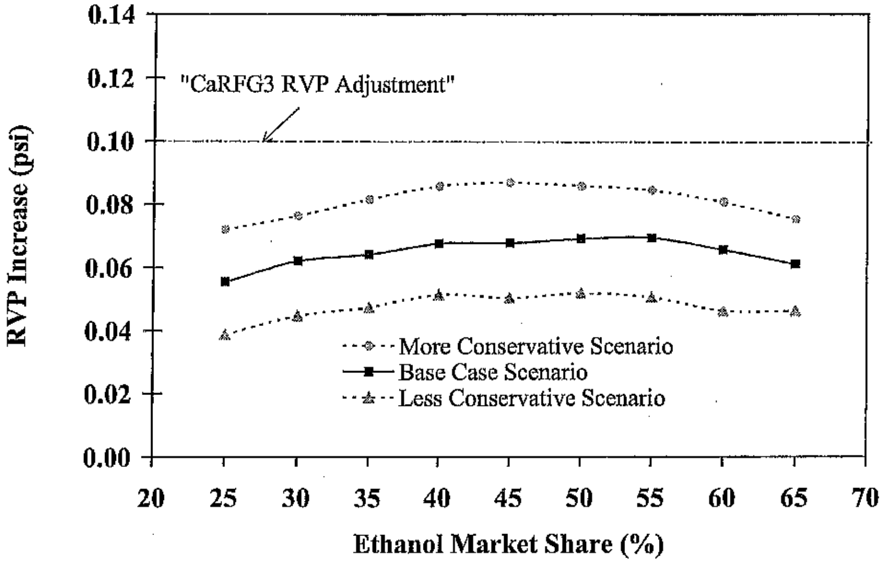
*These figures are calculated from the average RVP increases in each region weighted by the corresponding non-loyal consumer proportions and gasoline consumptions.

C. Overall Findings Of Simulation Modeling

Figure VII-1 combines the statewide commingling impacts of 6 volume percent ethanol blend for three different scenarios. The solid line curve represents the results of the base case scenario as a function of ethanol market share while the two dashed lines represent the results of the sensitivity analysis. As previously discussed, the 6 volume percent ethanol blends are the most likely ethanol fuels to be supplied to California. As can be seen in Figure VII-1 the statewide commingling impacts are estimated to be less than 0.1 psi RVP, which is below the 0.1 CaRFG3 RVP offset in the Predictive Model.

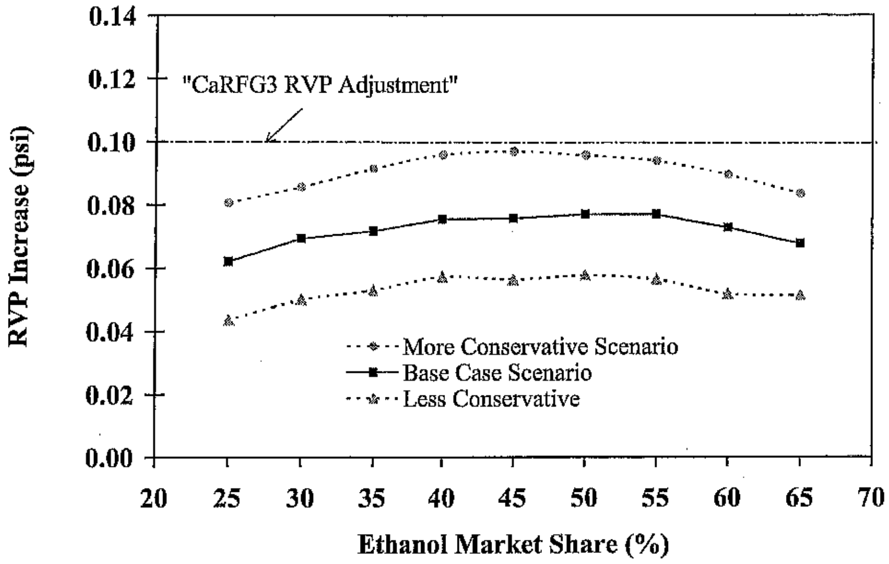
Similarly, Figure VII-2 represents the statewide commingling impacts of 7.7 volume percent ethanol blends. These blends produce somewhat higher commingling impacts than the 6 volume percent blends. However, all scenarios show that the impacts are less than 0.1 psi RVP.

Figure VII-1.*
Statewide Commingling Impacts Of 6 Vol% Ethanol Blend For Various Market Shares Using The 2001 ARB Field Study Input Parameters



*Each point represents a weighted average of regional RVP increase from 5000 consumers with 500 fuelings each.

Figure VII-2.*
Statewide Commingling Impacts Of 7.7 Vol% Ethanol Blend For Various Market Shares Using The 2001 ARB Field Study Input Parameters



*Each point represents a weighted average of regional RVP increase from 5000 consumers with 500 fuelings each.

D. Comparison of Field Observations to Simulation Results of Statewide Potential of Commingling Impacts

A unique feature of staff's commingling analysis is the ability to verify the commingling impacts that were observed in the field, which could not encompass a wide range of scenarios to the simulation results that would bridge these gaps. Conversely, using the simulation model staff was able to analyze possible commingling scenarios, which were unobserved in the field, and then use field observed commingling impacts to gauge the reasonableness of such analysis.

Based on this comparison, both the field observations and simulation modeling results are in good agreement to conclude that the statewide potential commingling impact of CaRFG3 is less than 0.1 psi RVP.

E. Other Factors that May Reduce the Commingling Impacts

It is likely that in certain areas, due to constraints in the fuel distribution systems, gasoline retailers would sell only one type of gasoline—either ethanol or non-ethanol blended gasoline—under different brand names. Although consumers described themselves as non-loyal with regard to gasoline brand, there should be limited commingling impacts in these "captive" areas.

VIII. ARB EVALUATION OF THE U.S. EPA COMMINGLING ANALYSIS

This chapter discusses staff's evaluation of the U.S. EPA's commingling analysis performed as part of their denial of California's request for a waiver of the federal oxygen mandate, including a comparison of the results of the U.S. EPA's analysis to that of the ARB.

C. U.S. EPA Findings on Commingling Impacts

Staff reviewed the U.S. EPA technical support document of potential commingling impacts in California, with the focus on the South Coast air basin, in response to Governor Davis' request for a waiver from the U.S. EPA from the federal oxygen requirement for federal reformulated gasoline areas. A copy of the U.S. EPA commingling analysis is provided in Appendix Q.

In its denial, the U.S. EPA stated that it believed there was great uncertainty regarding potential increases in VOC evaporative emissions from commingling in vehicle fuel tanks. U.S. EPA rejected ARB's conclusion that a 0.1 psi increase was most likely, and stated that the potential commingling impacts could range from greater than 0.1 up to 0.3 psi RVP. Using the upper end of this range, U.S. EPA concluded that the CaRFG3 regulations might not be sufficiently protective to prevent an overall increase in VOC emissions due to a large commingling effect.

D. Comparison of U.S. EPA and ARB Commingling Evaluations

Upon comparing the ARB and the U.S. EPA commingling analysis, staff observed several key differences in both methodology and use of data. These differences result in contrasting conclusions between the two analyses.

A distinct difference between the two analyses is in the way brand-loyal consumers, those who always purchase one brand of gasoline, are handled. Staff assumed no or negligible commingling effects from this group of consumers. In contrast, the U.S. EPA assumed the group would contribute to commingling.

For input data that are a function of future market provisions, staff relied on the most up-to-date and reliable sources. Except for ethanol purchase propensity, both analyses shared similar information. For example, staff adopted ethanol market penetration from a study under the U.S. EPA contract.

Both the ARB and the U.S. EPA had access to consumer fueling habits information that, while obtained from different sources, was quite similar. However, the handling of these data was very different between the ARB and the U.S. EPA. ARB staff took precautionary steps to verify that these data were representative to population, and compared them to reliable sources for accuracy. However, the U.S. EPA, apparently based on its own judgment of what might possibly occur, modified the data.

These modifications produced lower brand loyalty, lower percent of fillup, and higher initial fuel tank levels than used by the ARB staff. Each of these modifications leads to a higher commingling effect. ARB staff believes that the data collected in their field study conclusively demonstrates that the use of modified data by U.S. EPA does not represent fueling habits in California, and produced an over estimation of the commingling analysis for the state. As a result, the U.S. EPA's analysis is fundamentally flawed, and the conclusions are questionable[7].

Because of these factors, the U.S. EPA's analysis has resulted in a 0.1 to 0.3 psi range of RVP increases from commingling in the South Coast air basin, with 0.2 psi RVP chosen as the likely commingling impact (see Appendix Q). Given the field observations now available and an improved simulation model, staff believes that the U.S. EPA has grossly overestimated the potential commingling impacts by, at least, a factor of two.

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[7] A similar conclusion was reached in an analysis produced by Systems Applications International ("Analysis of Commingling Due to Ethanol Blends"). In that analysis, the validity of the U.S. EPA analysis was questioned. This analysis, using the same model, but inputting the actual U.S. EPA data instead (i.e., unmodified), concluded that using the modified data would result in commingling impacts approximately twice as high as what it would have been using the actual data. A copy of this analysis is provided in Appendix P.

Appendix A:

Working Group

Air Resources Board
CaRFG3 Commingling Study Working Group

NAME	COMPANY
Bruce Heine	Williams
Cal Hodge	A 2nd Opinion, Inc.
Chuck A. Le Tavec	BP
Dennis Lamb	DWL Services
Duong Trinh	ARB
Ellen Shapiro	Auto Alliance
Erik White	ARB
Fred Schmidt	ARB
Gary Whitten	ICF Consulting
Gina Grey	WSPA
Jim Uihlein	BP
John Freel	Chevron
Loren Beard	Daimler Chrysler
Micheal Okafor	ARB
Mike Ingham	Chevron
Neil Koehler	Kinenergy
Nelson Chan	ARB
Raak Veblen	ARB
Ramesh Ganeriwal	CEC
Steve Smith	Tosco Corp.
Thomas Eveland	Atty
Tom Koehler	Celilo Group

Appendix B:

Working Group Comments on Preliminary Draft Assessment

Major Comments from the Working Group and Peer Reviewer

On the ARB's Commingling Study

Date	Organization	Comment	Staff Comment / Action
4/9/2002	A 2nd Opinion, Inc. (Cal Hodge)	- Nothing substantial	- None
4/24/2002	Valero (Simone Yuan-Newman)	- Fuel weathering effect on commingling	- Field data are inconclusive - Low initial tank level so weathering may not play a major role
		- The adequacy of 5% tank 'heel' assumption	- A CRC study by SwRI (Aug. 2002) conforms that on average tank heel is about 5.2%
4/24/2002	Chevron (Lew Gibbs)	- Vehicle age distribution in 3 regions	- They are similar
		- Plot final RVP vs. dispensed RVP	- Will be added in the final report
		- Fuel weathering effect on commingling, especially in the Lake Tahoe area	- Same as above
		- Plot initial fuel tank level by region	- Will be added in the final report
		- The adequacy of 5% tank 'heel' assumption	- Same as above
5/7/2002	ExxonMobil (Craig P. Knoeller)	- CARB has overestimated the statewide commingling impacts by assuming that ethanol market penetration would be uniform throughout the state	- Will make adjustment to the analysis when information on fuel distribution constraints, under a waiver scenario, become more available
4/25/2002	UC, Berkeley (Rob Harley)	Fist Part: Field Study	
		- Avoid using 'statewide' term in commingling analysis, but focus more on urban areas (SF, LA)	- Will add more discussion to clarify the meaning of 'statewide' commingling impact, and add urban area analysis (LA) to address the U.S. EPA denial
		- Plot initial fuel tank level by region	- Same as above
		- Use 'quantitative' analysis of commingling	- Will include it as an addition or

Appendix C:

Fuel Sampling Protocol

CaRFG3 Commingling Study – Fuel Sampling Protocol

I. Introduction

In adopting the regulations for California Phase 3 reformulated gasoline (CaRFG3) by way of Resolution 99-39, the Board directed staff to further evaluate the expected real-world emissions impact of commingling CaRFG3 containing ethanol with CaRFG3 not containing ethanol in motor vehicle fuel tanks. Because as little as two volume percent ethanol in gasoline will raise its Reid vapor pressure (RVP) by about one pound per square inch (psi), commingling may result in increased evaporative motor vehicle emissions. The extent of commingling and its impact on evaporative emissions depends on several factors, including whether the federal reformulated gasoline year-round minimum oxygen requirement will continue to apply in California, refiner choices regarding the mix of oxygenated and non-oxygenated gasoline in a given area, and customer choices regarding brand and grade loyalty.

II. Field Study Overview

One aspect to be incorporated into the evaluation is a field study of the actual impacts of commingling fuels in vehicle fuel tanks. It is anticipated that this field study will be conducted at retail gasoline facilities in the Los Angeles, San Francisco, and Lake Tahoe areas of California. Sampling will be performed by teams consisting of three members each, with three teams deployed at three different stations on any given day. Teams will spend a minimum of one day at each station identified for participation in the study, two or three days in each geographical area. Although the actual time needed to draw a sample will be approximately 3 minutes, it is estimated that each team will be able to sample only about three vehicles per hour. Each team will likely collect about 35 fuel samples per day, resulting in between about 200 and 300 fuel samples generated per region. Vehicle fuel tank samples will be obtained from all customers willing to participate in the field study. The obtained fuel samples (including representative underground tank samples) will be analyzed for the fuel properties needed to evaluate the actual impact of commingling on vehicle evaporative emissions.

Fieldwork for this study will be conducted in two phases. The first phase, to be conducted in late June, was is to evaluate the efficacy of the draft fuel sampling protocol. Samples were will be taken from each of the service station's underground tanks upon arrival and departure at each test site. Vehicle fuel tank samples were will be obtained prior to refueling from all customers willing to participate. While the sampling and refueling operations were are taking place, the customers were will be interviewed to obtain information necessary for further evaluation. This information was will be recorded on field data sheets (sample attached) and will included a control number, sample identification numbers, date, time, year/make/model of vehicle, initial fuel gauge level, and amount (in gallons) and grade of product dispensed, and whether the customer had purchased a different brand of fuel within the last two refuelings. A second fuel sample was will be obtained from their vehicle tank after refueling. Experience gained in this first phase has been used to will determine if and how the draft sampling protocol could can be improved and finalized.

The second phase of fieldwork, to be conducted from early August July through late September August, will be the implementation of this the finalized sampling protocol. Samples will be taken from each of the service station's underground tanks upon arrival and departure at each test site. Vehicle fuel tank samples will be obtained prior to refueling from all customers willing to participate. While the sampling and refueling operations are taking place, the customer will be interviewed to obtain information necessary for further evaluation and to identify vehicles expected to have commingled fuel in their tank after refueling. This information will be recorded on field data sheets and will include a control number, sample identification numbers, date, time, year/make/model of vehicle, initial fuel gauge level, and amount (in gallons and dollars) and grade of product dispensed, and whether the customer had purchased a different brand of fuel within the last refueling. If an initial sample is successfully obtained from the vehicle fuel tank, a second fuel sample will be obtained from those vehicles expected to have commingled fuel in their tank after refueling. If an initial sample is not obtained from the vehicle fuel tank, a second fuel sample will not be taken. There will be two or three four different fuel samples that must be correctly identified and properly associated with each vehicle successfully tested.

Upon completion of the second phase of fieldwork, staff will evaluate the need to supplement the data with an additional focused study to better capture and characterize ethanol blends.

Samples from the vehicle tanks and the station's underground tanks will be obtained using American Society of Testing and Materials (ASTM) D 5842-95, "Standard Practice for Sampling and Handling of Fuels for Volatility Measurement". Vehicle tanks are not mentioned in the ASTM sampling method. However, we will be essentially following the tank tap portion of the sampling method using apparatus that the Air Resources Board (ARB) has successfully used for some time to obtain diesel samples from vehicle tanks to check for presence of red dye (see Section III.F for photos of apparatus). Special care will be taken to ensure that minimal evaporation takes place during the sampling process so that accurate RVP results will be obtained.

To minimize the amount of handling and the duration of sample storage prior to RVP analysis, samples will be analyzed for RVP in ARB's mobile laboratory that will be located in the general vicinity of the stations participating in the field study. This should enable the completion of most samples RVP analyses within 24 hours. All samples will be analyzed for RVP using ARB's "Test Method for the Determination of the Reid Vapor Pressure Equivalent Using an Automated Vapor Pressure Test Instrument" (see California Code of Regulation Title 13 §2297). All samples will subsequently be transported to ARB laboratory facilities in El Monte to be analyzed for the volumetric amount and type of oxygenate, as well as total oxygen content, by ASTM D 4815-94, "Standard Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C1 to C4 Alcohols in Gasoline by Gas Chromatography".

III. Sampling Protocol

A. Required Equipment

- 4-oz. clear glass sample bottles with lined plastic lids
- 1-liter aluminum sample bottles with foil lined plastic lids
- Polypropylene ¼ inch O.D. tubing
- ¼ inch x 25 ft. copper cooling coil
- 2 gal. round insulated water dispenser for cooling coil
- Ice & water
- Hand-operated vacuum pump
- Sample labels/Field data sheets
- Nozzle extension
- Sectioned boxes for 4-oz. bottle storage
- Ice chests for sample bottle conditioning and sample storage
- Cleanup and equipment maintenance supplies
- 16-20 oz. glass wash bottle
- Product rinse container (portable gas can)

B. Sampling Procedures

1) Vehicle Tank Sampling

A modified version of ASTM D 5842-95 will be used to obtain the vehicle fuel tank samples. While this method does not specifically address sampling from a vehicle fuel tank, the tank tap sampling procedure is being adapted to accommodate our specific needs. The sampling equipment is the same equipment that has been successfully used in ARB's ongoing program to sample vehicle fuel tanks to test for red dyed diesel fuel, with the addition of a copper cooling coil to condition the sample. Approximately 16 oz. of fuel will be removed from the vehicle tank for each 4-oz. sample obtained.

Prior to drawing each individual sample, the capped 4-oz. glass sample bottle will be chilled in an ice bath and preconditioned with the fuel to be sampled. To obtain the sample, a polypropylene sample line connected to the inlet of the cooling coil will be inserted into the vehicle's fuel fill pipe until it reaches product. The sampling apparatus will be flushed with product prior to obtaining the sample. A 16-20 oz. glass wash bottle will be connected to the hand-operated vacuum pump with the outlet end of the cooling coil inserted through the pump compression fitting into the bottom of the bottle. To adequately flush the sample line and cooling coil, approximately 10 oz. of fuel will be drawn through the apparatus into the wash bottle. The wash bottle will then be replaced with a clean, chilled, 4-oz. glass sample bottle and an additional 1 oz. of fuel will then be pumped into the sample bottle for preconditioning. The preconditioning fuel will then be discarded from the 4-oz. glass sample bottle and then poured into the wash container prior to obtaining the actual sample. All This wash material will be collected and disposed of according to the procedures described in Section E of this protocol. The sample will then be obtained by pumping additional fuel through the preconditioned apparatus. When the bottle is 70 to 85% full, it will be disconnected from the pump, capped, labeled, and stored in a cool location out of direct sunlight. All sample labels will include both the sample identification number and the unique control number associated with each participating sample vehicle. Care will be taken to minimize the amount of time the sample bottle is uncapped to avoid the potential for sample contamination from water condensation inside the bottle.

Samples containing visible water or other unusual contamination will not be considered valid for the purposes of this study and shall be disposed. Since the pump works on a vacuum principle, a negative pressure will be produced within the bottle. As a result, no product will touch the pump itself but instead will be drawn from the vehicle fuel tank through the sample line, through the cooling coil, and bottom-fill the 4-oz. glass sample bottle. If any product is accidentally drawn into the pump by overfilling or tipping the bottle, the pump will be disassembled, wiped down with a clean, dry shop towel, and air-dried prior to its next use.

2) Service Station Nozzle Sampling

ASTM D 5842-95 will be used to obtain samples from the service station's underground tanks for all grades dispensed at the station. Although this method allows the use of 4-oz. sample bottles, 1-liter sample bottles will be used due to their ease of use when obtaining a dispenser sample. The 1-liter sample bottles will be chilled in ice water prior to and while obtaining a sample. The bottle will be rinsed with product and drained before being bottom-filled with a nozzle extension attached to the service station dispenser nozzle. After the bottle is filled between 70 to 85% full, the bottle will be capped, labeled, and stored in a cool location out of direct sunlight. Care will be taken to minimize the amount of time the sample bottle is uncapped to avoid the potential for sample contamination from water condensation inside the bottle.

C. Sample Handling Procedures

It is essential that proper sample identification and field data sheet referencing is completed for each vehicle sample set. Preformatted Preprinted self-adhesive sample identification labels will be completed and attached to each sample bottle with each sample identification number also being recorded on the and corresponding field data sheet. Label ink and adhesive will be resistant to water and gasoline to assure identification integrity. Vapor pressures are extremely sensitive to evaporation loses and to slight changes in composition. Necessary precautions will be observed when handling samples to ensure the samples are representative of the product and satisfactory for RVP analysis.

D. Analytical Methods

Fuel samples obtained will be analyzed by the following methods:

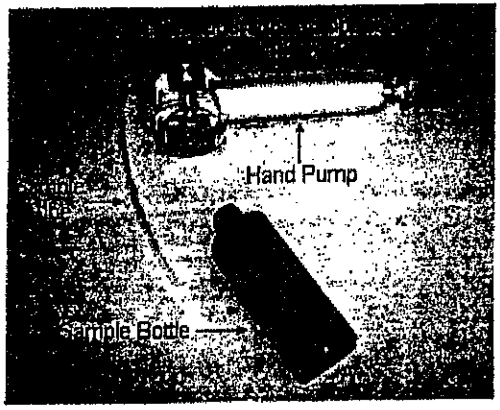
Fuel Quality	Analysis Method
RVP (psi)	CCR Title 13 §2297*
Oxygen Content (wt.%)	ASTM D 4815-94
MTBE (vol.%)	ASTM D 4815-94
Ethanol (vol.%)	ASTM D 4815-94

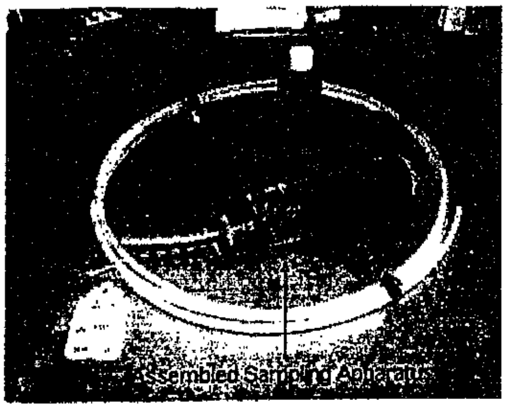
*Paragraph (d)(1.0) which specifies a Title 13 sampling method will be replaced with ASTM D 5842 sampling method which allows for the use of either 32-oz or 4-oz bottles.

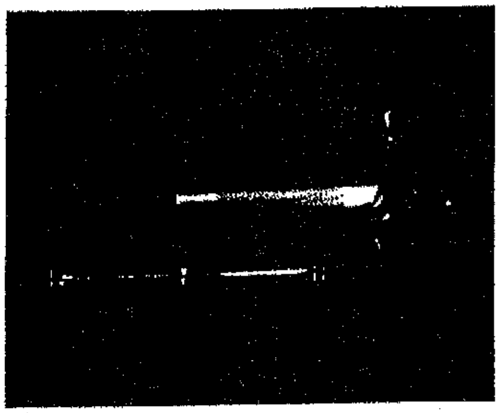
E. Disposal of Fuel Samples & Wash Materials

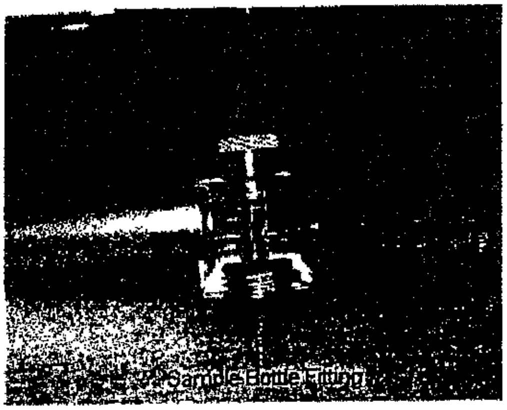
All waste gasoline generated from the sampling and analytical procedures will be collected in approved gasoline storage containers and disposed of at authorized gasoline recycling facilities.

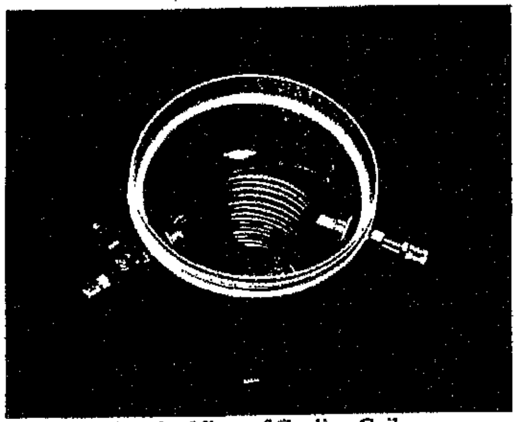
F. Tank Sampling Apparatus



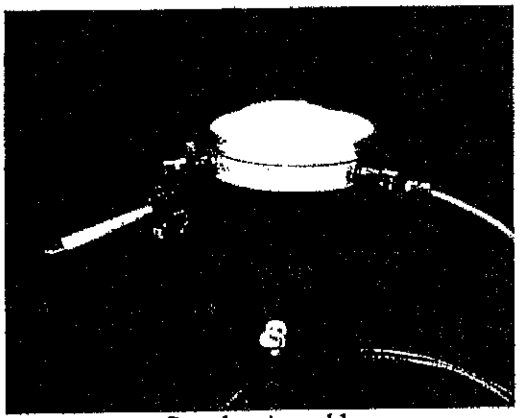








Interior View of Cooling Coil



Complete Assembly

FIELD DATA SHEET

CaRFG3 Commingling Study - Fuel Sampling Program

Date: __________ Time: ________ Control No: __________

Vehicle Information

Year: ______________________ Make: ______________________

Model: ______________________ Fuel Gauge: E --------\--------|--------/-------- F

1st Sample Obtained? Yes ___ No ___ Sample No: ______________________

Refueling Information

Brand: __________ Grade: ________ Amount: $ ________ & ________ gal.

Was a different brand of gasoline used for the last refueling? Yes ___ No ___ ? ___

2nd Sample Obtained? Yes ___ No ___ Sample No: ______________________

Sampling Team Member: ______________________________

(Certification from a team member that is not the custodian that the test was performed)

Customer's Name: ______________________________

Customer's Signature: ______________________________

(Required for accounting purposes. Signature acknowledges receipt of $5 payment for services.)

Script

Action	Elapsed Time
Customer enters station, is greeted by team member, and offered incentive for voluntary participation in study.	00:00.30
Team proceeds to obtain initial sample and vehicle information.	00:03.30
Customer refuels vehicle.	00:06.30
Team proceeds to obtain second sample, completes field data sheet.	00:09.30
Customer's signature is obtained in exchange for payment of incentive.	00:10.00

Appendix D:

Field Study Data Set

CaRFG3 Commingling Study Fuel Sampling Data

control no.	vehicle information				got 1^{st}	rvp^1	wt% O$_2^1$	volume %			refueling information						got 2^{nd}	rvp^2	wt% O$_2^2$	volume %			rvp^{am}	wt% O$_2^{am}$	volume %			rvp^{pm}	wt% O$_2^{pm}$	volume %		
	year	make	model	gage				eth^1	mtbe^1	tam^1	site	grd	cost	gal	fill	dif				eth^2	mtbe^2	tam^2			eth^{am}	mtbe^{am}	tam^{am}			eth^{pm}	mtbe^{pm}	tam^{pm}
LT1-01	2000	Saturn	SL2	E	1	6.87	2.06	0.00	11.31	0.00	no.1	R	16.80	10.53	1	1	1	6.96	2.21	5.06	1.79	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-02	1988	Subaru	DL	5/8	0						no.1	R	10.00	6.50	0	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-03	1990	Toyota	PU	E	1	6.48	0.45	0.04	2.22	0.00	no.1	R	23.42	15.22	1	1	1	6.87	2.01	5.15	0.52	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-04	2001	Chev	Lumina	3/4	0						no.1	R			1	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-05	1997	Honda	Civic CX	E	0						no.1	R	14.31	9.30	1	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-06	1986	Toyota	4Runner	1/4	1	7.18	0.56	0.89	1.09	0.00	no.1	R	5.00	3.25	0	1	1	7.61	1.25	2.98	0.79	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-07	1995	Ford	Explorer	1/8	1	7.09	1.65	4.30	0.29	0.00	no.1	R	26.26	17.07	1	0	1	6.85	2.11	5.56	0.25	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-08	1977	Dodge	Sprtsmn Vn	7/8	1	7.56	0.76	1.91	0.26	0.00	no.1	R	19.31	12.55	1	0	1	8.21	0.95	2.42	0.27	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-09	1997	Jeep	Cherokee	E	1	6.61	0.08	0.00	0.29	0.00	no.1	R	10.00	6.50	0	1	1	6.98	1.85	4.86	0.24	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-10	1997	Chev	Silverado PU	5/8	1	6.35	1.93	0.00	10.54	0.00	no.1	R	18.60	12.09	1	1	1	6.87	2.15	3.07	5.54	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-11	1973	Chev	1T PU	1/8	1	6.25	1.67	4.39	0.24	0.00	no.1	R	21.20	13.78	1	1	1	6.56	1.88	4.94	0.25	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-12	1996	Chev	1500 PU	E	1	6.72	1.95	5.08	0.35	0.00	no.1	R	33.70	21.90	1	0	1	6.76	2.26	5.97	0.25	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-13	1999	Dodge	Caravan	1/8	1	6.28	1.99	0.00	10.92	0.00	no.1	R	20.00	13.00	1	1	1	6.83	2.19	4.34	3.14	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-14	1999	Toyota	Tacoma PU	E	1	6.87	1.48	3.85	0.25	0.00	no.1	R	10.00	6.50	0	1	1	6.73	2.23	5.90	0.25	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-15	1999	Mitsubishi	Mirage	1/2	1	6.63	1.68	0.38	7.82	0.70	no.1	P	7.77	4.47	1	1	1	6.90	1.82	2.29	4.93	0.46	6.70	2.09	5.50	0.25	0.00	6.66	2.08	5.48	0.25	0.00
LT1-16	1993	VW	Eurovan	1/4	1	6.28	1.02	0.00	5.57	0.00	no.1	R	22.77	14.80	1	1	1	6.98	1.89	4.18	1.84	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-17	1990	Lincoln	Towncar	1/4	1	6.83	1.97	5.30	0.00	0.00	no.1	R	17.06	11.08	1	1	1	6.74	2.17	5.74	0.23	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-18	1977	Jeep	CJS	E	0						no.1	R	26.08	16.95	1	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-19	2001	Toyota	4Runner	E	1	6.24	1.74	0.00	9.53	0.00	no.1	R	26.01	16.90	1	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-20	2000	Jeep	Cherokee	1/8	1	6.11	0.07	0.03	0.34	0.00	no.1	R	10.00	6.50	0	1	1	6.95	1.76	4.60	0.27	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-21	2000	Ford	Expedition	1/4	0						no.2	R	32.65	18.15	1	0	0						6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-22	1989	Jeep	Cherokee	E	1	6.93	0.05	0.00	0.29	0.00	no.2	R	4.77	2.65	0	1	1	6.53	0.06	0.00	0.31	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-23	1988	Ford	F250 PU	E	1	6.16	0.62	0.00	3.37	0.00	no.2	M	13.00	5.70	0	0	1	6.45	0.27	0.00	1.47	0.00	6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-24	1991	Mercedes	500SL	E	1	6.56	1.87	0.00	10.24	0.00	no.2	P	37.15	18.40	1	0	1	6.38	0.28	0.00	1.53	0.00	6.28	0.05	0.00	0.25	0.00	6.27	0.04	0.00	0.24	0.00
LT1-25	2000	GMC	Jimmy	1/4	1	6.74	0.14	0.00	0.57	0.00	no.2	R	6.01	3.34	0	?	1	6.76	0.09	0.00	0.48	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-26	1989	Chev	Blazer	1/4	1	6.4	0.05	0.00	0.28	0.00	no.2	M	20.03	10.38	0	0	1	6.48	0.05	0.00	0.29	0.00	6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-27	1993	Jeep	Cherokee	E	1	6.61	2.00	0.53	9.24	0.70	no.2	R	10.00	5.56	0	1	1	6.70	0.57	0.10	2.79	0.14	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-28	2002	Mercedes	C320 Sptwgn	1/4	0						no.2	M	22.07	11.44	1	1	0						6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-29	2000	Chrysler	Concorde	1/4	0						no.2	R	20.25	11.26	1	0	0						6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-30	1997	Ford	Contour	E	1	6.89	0.24	0.04	1.04	0.24	no.2	R	6.17	3.43	0	0	1	6.73	0.12	0.00	0.64	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-31	2001	Lexus	ES300	1/8	0						no.2	M	27.38	14.19	1	0	0						6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-32	1967	GMC	PU	1/8	1	6.43	0.33	0.00	1.82	0.00	no.2	R	17.65	9.81	0	0	1	6.56	0.14	0.00	0.79	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-33	1999	Ford	Ranger PU	E	0						no.2	R	25.38	14.11	1	1	0						6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-34	2000	VW	Passat	1/4	0						no.2	M	21.79	10.79	1	1	0						6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-35	1987	Saab		E	1	6.25	0.22	0.00	1.19	0.00	no.2	R	10.00	5.56	0	1	1	6.45	0.12	0.00	0.67	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-36	1985	Audi	4000S	E	1	6.41	1.27	0.00	5.62	1.51	no.2	R	10.00	5.56	0	1	1	6.56	0.37	0.00	1.69	0.35	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-37	1996	Dodge	Caravan	5/8	1	6.72	0.25	0.00	1.39	0.00	no.2	R	12.98	7.22	1	0	1	6.69	0.19	0.00	1.02	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00

CaRFG3 Commingling Study Fuel Sampling Data

control no.	vehicle information				got 1^{st}	rvp^1	wt% O_2^1	volume %			refueling information						got 2^{nd}	rvp^2	wt% O_2^2	volume %			rvp^{am}	wt% O_2^{am}	volume %			rvp^{pm}	wt% O_2^{pm}	volume %		
	year	make	model	gage				eth^1	$mtbe^1$	tam^1	site	grd	cost	gal	fill	dif				eth^2	$mtbe^2$	tam^2			eth^{am}	$mtbe^{am}$	tam^{am}			eth^{pm}	$mtbe^{pm}$	tam^{pm}
LT1-38	1998	GMC	Sonoma	E	1	6.86	0.09	0.00	0.29	0.00	no.2	M	29.00	15.03	1	1	1	6.63	0.05	0.00	0.30	0.00	6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-39	1998	Subaru	Outback	E	1	6.44	0.09	0.00	0.33	0.00	no.2	M	24.98	12.95	1	1	1	6.60	0.05	0.00	0.29	0.00	6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-40	1993	Isuzu	Trooper	E	1	6.5	0.07	0.00	0.39	0.00	no.2	R	19.92	11.08	0	0	1	6.60	0.06	0.00	0.32	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-41	2001	Ford	150 PU	E	1	6.8	0.91	2.33	0.24	0.00	no.3	R	15.00	9.56	0	1	1	6.99	1.75	4.60	0.21	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-42	2001	Volvo	S80	1/4	0						no.3	R	18.49	11.78	1	1	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-43	1971	Chev	Blazer	3/4	1	6.93	1.79	4.71	0.22	0.00	no.3	R	8.35	5.32	1	1	1	6.89	1.78	4.80	0.00	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-44	1992	Mercury	Sable	5/8	1	6.44	1.89	0.00	10.36	0.00	no.3	R	10.00	6.37	1	1	1	6.90	1.88	2.14	5.93	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-45	1999	Cadillac	DeVille	3/4	1	6.53	2.01	2.49	5.93	0.00	no.3	P	13.00	7.35	0	1	1	6.70	2.03	3.42	4.15	0.00	6.80	2.09	5.46	0.36	0.00	6.79	2.09	5.48	0.33	0.00
LT1-46	1999	Hyundai	Elantra	1/4	0						no.3	R	10.00	6.37	0	1	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-47	2001	Chrysler	T&C Van	1/2	1	6.4	1.54	0.00	8.44	0.00	no.3	R	18.00	11.47	1	1	1	6.96	1.79	3.20	3.30	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-48	1993	Mercury	Grd Marquis	1/4	1	6.31	1.84	0.00	10.07	0.00	no.3	R	20.48	13.05	1	1	1	6.96	1.87	3.04	4.08	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-49	1987	Hyundai	Excel	1/4	1	6.79	2.07	5.46	0.24	0.00	no.3	R	10.00	5.99	0	0	1	6.87	2.06	5.42	0.28	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-50	1979	Toyota	PU	E	1	6.82	1.91	3.11	3.90	0.29	no.3	R	10.00	6.37	0	1	1	6.87	1.99	4.87	0.97	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-51	2001	Dodge	Caravan	3/8	1	6.22	1.90	0.05	9.98	0.38	no.3	R	21.01	13.39	1	1	1	6.90	1.94	3.83	2.85	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-52	1995	Toyota	Corolla	3/8	0						no.3	R	12.24	7.80	1	0	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-53	1998	Chev	1500 PU	1/4	0						no.3	R	35.00	22.31	1	1	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-54	2001	Ford	Taurus	1/4	0						no.3	R	16.50	10.52	1	1	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-55	1985	Toyota	PU	1/8	1	7.54	0.61	1.42	0.29	0.00	no.3	R	10.00	6.37	0	0	1	7.22	1.25	3.26	0.24	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-56	1984	Nissan	Maxima	1/8	1	7.31	0.39	0.91	0.27	0.00	no.3	M	20.41	12.20	1	0	1	6.99	1.66	4.35	0.27	0.00	6.79	2.09	5.46	0.35	0.00	6.92	2.06	5.40	0.27	0.00
LT1-57	1993	Toyota	PU	1/8	1	6.76	0.39	0.20	1.73	0.00	no.3	R	10.00	6.37	0	1	1	7.09	1.55	3.85	0.66	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-58	1993	Lincoln	Towncar	3/8	1	6.72	1.96	4.68	1.23	0.00	no.3	R	17.03	10.86	1	0	1	6.86	1.97	5.00	0.65	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-59	1991	Mercury	Topaz	E	1	6.93	1.34	3.44	0.26	0.00	no.3	R	5.00	3.19	0	1	1	6.92	1.69	4.44	0.21	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-60	1993	Ford	Ranger PU	E	1	6.25	0.07	0.00	0.30	0.00	no.3	R	27.80	17.72	1	1	1	6.95	1.66	4.36	0.21	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT2-01	1998	Dodge	Durango	7/8	1	7.01	2.08	2.49	6.12	0.22	no.4	M	10.00	6.10	1	1	1	7.06	1.59	1.87	4.77	0.17	6.43	0.06	0.00	0.34	0.00	6.44	0.06	0.00	0.30	0.00
LT2-02	1992	Honda	Accord	1/4	0						no.4	R	8.00	5.20	0	1	0						6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-03	1983	Dodge	Ram PU	E	1	6.51	1.06	0.00	5.80	0.00	no.4	R	6.01	3.91	0	0	1	6.57	0.56	0.00	3.09	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-04	1991	Nissan	Pathfinder	1/8	1	6.67	0.12	0.00	0.52	0.00	no.4	R	25.32	16.45	1	1	1	6.60	0.08	0.00	0.41	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-05	1995	Chevy	Astro	1/4	1	6.45	2.00	0.00	10.59	0.00	no.4	R	7.00	4.55	0	1	1	6.50	1.29	0.00	6.90	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-06	1998	Ford	Escort	1/4	0						no.4	R	10.00	6.50	0	1	0						6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-07	1999	Chevy	Astro	1/4	1	6.47	2.04	0.00	10.29	1.00	no.4	R	22.23	14.45	1	1	1	6.56	0.82	0.00	4.14	0.41	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-08	1993	Chevy	1500 PU	1/8	1	8.01	0.07	0.00	0.36	0.00	no.4	R	31.33	20.34	1	0	1	6.87	0.07	0.00	0.37	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-09	1991	Dodge	Shadow	1/4	1	6.74	2.19	0.00	9.20	0.00	no.4	R	11.45	7.44	1	1	1	6.87	0.90	0.00	3.95	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-10	1978	Toyota	PU	1/2	1	6.64	2.01	0.00	11.04	0.00	no.4	R	12.50	8.12	1	1	1	6.69	1.05	0.00	5.77	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-11	2001	Toyota	Avalon	1/4	0						no.4	R	19.25	12.51	1	1	0						6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-12	1994	Ford	Ranger	1/4	1	6.61	0.06	0.00	0.31	0.00	no.4	R	10.00	6.50	0	1	1	6.64	0.07	0.00	0.36	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-13	2000	Dodge	Intrepid	1/2	0						no.4	R	13.49	8.77	1	1	0						6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-14	1997	Toyota	Tacoma	E	1	6.87	2.04	0.00	1.82	0.00	no.4	R	10.00	6.50	0	1	1	7.28	0.60	0.00	0.81	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00

VII. SIMULATION RESULTS

This chapter describes the results of staff's use of the UCD simulation model to access the potential impacts of CaRFG3 commingling.

A. Statewide Potential Commingling Impacts

Using the UCD simulation model and assumed future ethanol market conditions (as discussed in Chapter VI), as well as consumer fueling behavior from the field study (as described in Chapter IV) as input, staff simulated a total of 162 fueling scenarios. These included all possible combinations of:

- 3 regions;
- 3 ethanol purchase propensity distributions;
- 9 ethanol market shares from 25 percent to 65 percent in five percent increments, and;
- 2 ethanol blends, 6 volume percent and 7.7 volume percent.

Each scenario represents 5,000 consumers with 500 fuelings per consumer, resulting in the modeling of over 400 million fuelings. The model then computes the average commingling effect for each scenario.

The first set of scenarios (i.e., ethanol purchase propensity based on a beta distribution, with $\alpha + \beta$ equal to 2) is collectively called the base case scenario. Table VII-1 summarizes the results of the base case scenario. The top half (above solid line) of Table VII-1 shows the commingling impacts of using a 6 volume percent ethanol blend while the bottom half shows the impacts of using a 7.7 volume percent blend. The two blends are assumed to have the same base RVP. RVP increases due to commingling are estimated for each region, as shown in Appendix O. These increases are weighted by the corresponding regional non-loyal consumer proportions and gasoline consumptions as described in Chapter VI, and the results are presented in Table VII-1. The last column in Table VII-1 is the total statewide commingling impact as the sum of the three regions weighted-average RVP increases for each ethanol market penetration. For example, if ethanol market share is 25 percent of total gasoline pool, the regional commingling contribution are estimated to be 0.002 psi, 0.020 psi, and 0.033 psi RVP in Lake Tahoe, the Bay Area, and Los Angeles, respectively, for 6 volume percent ethanol blends.

As expected, the anticipated commingling effect increases with ethanol market penetration, and peaks at around 45 percent to 50 percent market share. For the base case scenario, the model estimated average statewide commingling impacts of 0.055-0.069 psi RVP for 6 volume percent ethanol blends and 0.062-0.077si RVP for 7.7 volume percent ethanol blends.

Table VII-1
Estimated Statewide Commingling Impacts For Various Ethanol Blends And Market Shares Using The 2001 ARB Field Study Input Parameters

Base Case Scenario (Beta Distribution, $\alpha+\beta=2$)

(Draft)

Ethanol Market Share (%)	Ethanol Content (%vol)	Base RVP Non-Oxy Fuel (psi)	Base RVP Ethanol Fuel (psi)	Estimated RVP Increase Due To Commingling By Region (psi)			
				Lake Tahoe*	Bay Area*	Los Angeles*	Statewide*
25	6	6.71	5.74	0.002	0.020	0.033	0.055
30	6	6.71	5.74	0.002	0.022	0.037	0.062
35	6	6.71	5.74	0.002	0.022	0.040	0.064
40	6	6.71	5.74	0.002	0.022	0.043	0.067
45	6	6.71	5.74	0.003	0.024	0.041	0.068
50	6	6.71	5.74	0.003	0.024	0.042	0.069
55	6	6.71	5.74	0.002	0.024	0.043	0.069
60	6	6.71	5.74	0.002	0.024	0.039	0.066
65	6	6.71	5.74	0.002	0.022	0.037	0.061
25	7.7	6.71	5.74	0.002	0.022	0.037	0.062
30	7.7	6.71	5.74	0.002	0.025	0.042	0.069
35	7.7	6.71	5.74	0.003	0.025	0.044	0.072
40	7.7	6.71	5.74	0.003	0.025	0.048	0.075
45	7.7	6.71	5.74	0.003	0.027	0.046	0.076
50	7.7	6.71	5.74	0.003	0.027	0.047	0.077
55	7.7	6.71	5.74	0.003	0.026	0.048	0.077
60	7.7	6.71	5.74	0.003	0.026	0.044	0.073
65	7.7	6.71	5.74	0.002	0.025	0.041	0.068

*These figures are calculated from the average RVP increases in each region weighted by the corresponding non-loyal consumer proportions and gasoline consumptions.

B. Sensitivity Analysis

Using the UCD model, staff also performed sensitivity analysis of potential commingling impacts. The sensitivity analysis is related to staff's input assumptions, regarding different ethanol purchase propensities.

The results of this sensitivity analysis are shown in Tables VII-2 and VII-3. Table VII-2 presents a more conservative ($\alpha + \beta=5$) estimate of commingling impacts relative to the base case while Table VII-3 is less conservative ($\alpha + \beta=2$) compared to the base case.

Using the same methodology as in the base case, the statewide commingling impacts were estimated. Again as can be seen in the tables, the largest impacts occur when the ethanol market share is around 45 percent to 50 percent.

Table VII-2
Estimated Statewide Commingling Impacts For Various Ethanol Blends And Market Shares
Using The 2001 ARB Field Study Input Parameters
More Conservative Scenario (Beta Distribution, $\alpha+\beta=5$)
(Draft)

Ethanol Market Share (%)	Ethanol Content (%vol)	Base RVP Non-Oxy Fuel (psi)	Base RVP Ethanol Fuel (psi)	Estimated RVP Increase Due To Commingling By Region (psi)			
				Lake Tahoe*	Bay Area*	Los Angeles*	Statewide*
25	6	6.71	5.74	0.003	0.026	0.043	0.072
30	6	6.71	5.74	0.003	0.028	0.046	0.076
35	6	6.71	5.74	0.003	0.029	0.050	0.082
40	6	6.71	5.74	0.003	0.031	0.052	0.086
45	6	6.71	5.74	0.003	0.030	0.054	0.087
50	6	6.71	5.74	0.003	0.030	0.053	0.086
55	6	6.71	5.74	0.003	0.030	0.052	0.084
60	6	6.71	5.74	0.003	0.028	0.050	0.081
65	6	6.71	5.74	0.003	0.026	0.046	0.075
25	7.7	6.71	5.74	0.003	0.029	0.048	0.081
30	7.7	6.71	5.74	0.003	0.031	0.052	0.086
35	7.7	6.71	5.74	0.003	0.032	0.056	0.091
40	7.7	6.71	5.74	0.003	0.034	0.058	0.096
45	7.7	6.71	5.74	0.003	0.034	0.060	0.097
50	7.7	6.71	5.74	0.003	0.033	0.059	0.096
55	7.7	6.71	5.74	0.003	0.033	0.057	0.094
60	7.7	6.71	5.74	0.003	0.031	0.055	0.090
65	7.7	6.71	5.74	0.003	0.029	0.051	0.083

*These figures are calculated from the average RVP increases in each region weighted by the corresponding non-loyal consumer proportions and gasoline consumptions.

Table VII-3
Estimated Statewide Commingling Impacts For Various Ethanol Blends And Market Shares
Using The 2001 ARB Field Study Input Parameters
Less Conservative Scenario (Beta Distribution, $\alpha+\beta=1$)
(Draft)

Ethanol Market Share (%)	Ethanol Content (%vol)	Base RVP Non-Oxy Fuel (psi)	Base RVP Ethanol Fuel (psi)	Estimated RVP Increase Due To Commingling By Region (psi)			
				Lake Tahoe*	Bay Area*	Los Angeles*	Statewide
25	6	6.71	5.74	0.001	0.014	0.023	0.039
30	6	6.71	5.74	0.002	0.017	0.026	0.045
35	6	6.71	5.74	0.002	0.017	0.028	0.047
40	6	6.71	5.74	0.002	0.018	0.032	0.051
45	6	6.71	5.74	0.002	0.017	0.031	0.050
50	6	6.71	5.74	0.002	0.019	0.031	0.052
55	6	6.71	5.74	0.002	0.018	0.031	0.051
60	6	6.71	5.74	0.002	0.017	0.028	0.046
65	6	6.71	5.74	0.002	0.017	0.027	0.046
25	7.7	6.71	5.74	0.002	0.016	0.026	0.043
30	7.7	6.71	5.74	0.002	0.019	0.029	0.050
35	7.7	6.71	5.74	0.002	0.019	0.032	0.053
40	7.7	6.71	5.74	0.002	0.020	0.035	0.057
45	7.7	6.71	5.74	0.002	0.019	0.035	0.056
50	7.7	6.71	5.74	0.002	0.021	0.034	0.058
55	7.7	6.71	5.74	0.002	0.020	0.034	0.056
60	7.7	6.71	5.74	0.002	0.019	0.031	0.052
65	7.7	6.71	5.74	0.002	0.019	0.031	0.051

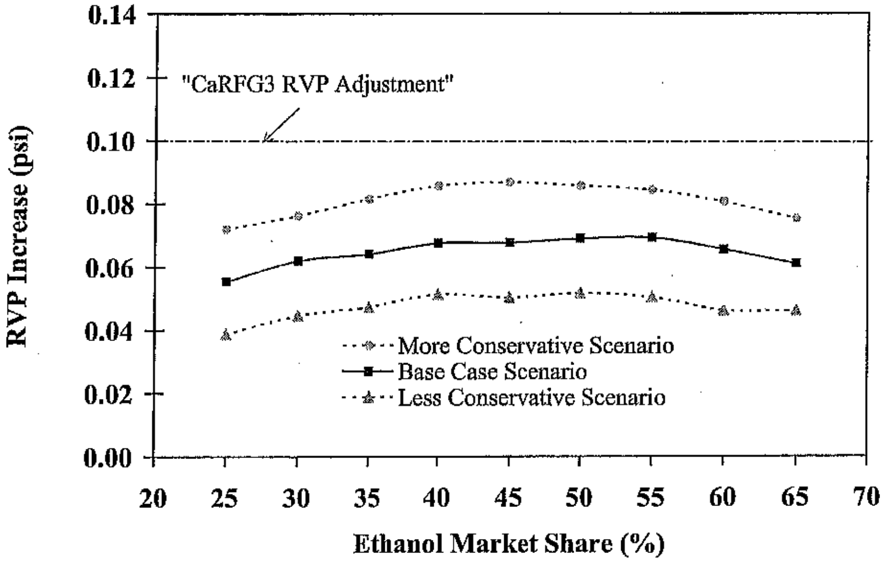
*These figures are calculated from the average RVP increases in each region weighted by the corresponding non-loyal consumer proportions and gasoline consumptions.

C. Overall Findings Of Simulation Modeling

Figure VII-1 combines the statewide commingling impacts of 6 volume percent ethanol blend for three different scenarios. The solid line curve represents the results of the base case scenario as a function of ethanol market share while the two dashed lines represent the results of the sensitivity analysis. As previously discussed, the 6 volume percent ethanol blends are the most likely ethanol fuels to be supplied to California. As can be seen in Figure VII-1 the statewide commingling impacts are estimated to be less than 0.1 psi RVP, which is below the 0.1 CaRFG3 RVP offset in the Predictive Model.

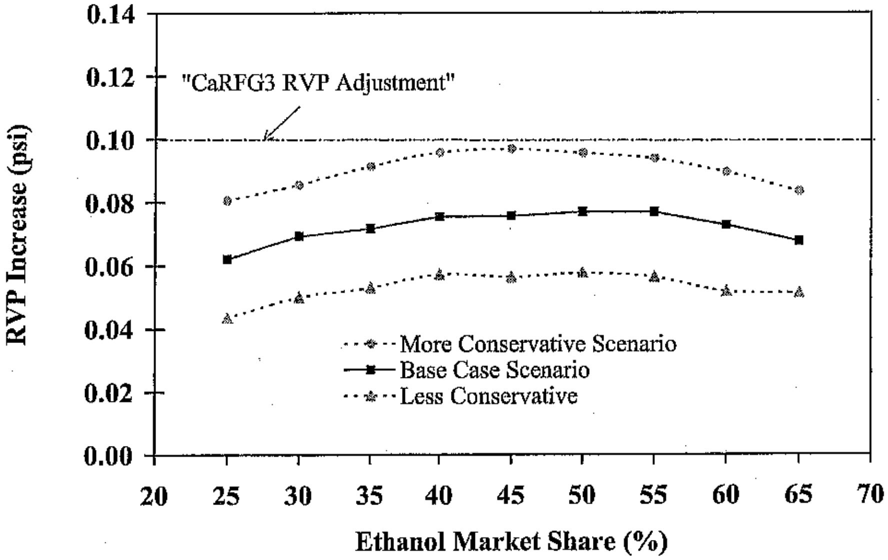
Similarly, Figure VII-2 represents the statewide commingling impacts of 7.7 volume percent ethanol blends. These blends produce somewhat higher commingling impacts than the 6 volume percent blends. However, all scenarios show that the impacts are less than 0.1 psi RVP.

Figure VII-1.*
Statewide Commingling Impacts Of 6 Vol% Ethanol Blend For Various Market Shares Using The 2001 ARB Field Study Input Parameters



*Each point represents a weighted average of regional RVP increase from 5000 consumers with 500 fuelings each.

Figure VII-2.*
Statewide Commingling Impacts Of 7.7 Vol% Ethanol Blend For Various Market Shares Using The 2001 ARB Field Study Input Parameters



*Each point represents a weighted average of regional RVP increase from 5000 consumers with 500 fuelings each.

D. Comparison of Field Observations to Simulation Results of Statewide Potential of Commingling Impacts

A unique feature of staff's commingling analysis is the ability to verify the commingling impacts that were observed in the field, which could not encompass a wide range of scenarios to the simulation results that would bridge these gaps. Conversely, using the simulation model staff was able to analyze possible commingling scenarios, which were unobserved in the field, and then use field observed commingling impacts to gauge the reasonableness of such analysis.

Based on this comparison, both the field observations and simulation modeling results are in good agreement to conclude that the statewide potential commingling impact of CaRFG3 is less than 0.1 psi RVP.

E. Other Factors that May Reduce the Commingling Impacts

It is likely that in certain areas, due to constraints in the fuel distribution systems, gasoline retailers would sell only one type of gasoline—either ethanol or non-ethanol blended gasoline—under different brand names. Although consumers described themselves as non-loyal with regard to gasoline brand, there should be limited commingling impacts in these "captive" areas.

VIII. ARB EVALUATION OF THE U.S. EPA COMMINGLING ANALYSIS

This chapter discusses staff's evaluation of the U.S. EPA's commingling analysis performed as part of their denial of California's request for a waiver of the federal oxygen mandate, including a comparison of the results of the U.S. EPA's analysis to that of the ARB.

C. U.S. EPA Findings on Commingling Impacts

Staff reviewed the U.S. EPA technical support document of potential commingling impacts in California, with the focus on the South Coast air basin, in response to Governor Davis' request for a waiver from the U.S. EPA from the federal oxygen requirement for federal reformulated gasoline areas. A copy of the U.S. EPA commingling analysis is provided in Appendix Q.

In its denial, the U.S. EPA stated that it believed there was great uncertainty regarding potential increases in VOC evaporative emissions from commingling in vehicle fuel tanks. U.S. EPA rejected ARB's conclusion that a 0.1 psi increase was most likely, and stated that the potential commingling impacts could range from greater than 0.1 up to 0.3 psi RVP. Using the upper end of this range, U.S. EPA concluded that the CaRFG3 regulations might not be sufficiently protective to prevent an overall increase in VOC emissions due to a large commingling effect.

D. Comparison of U.S. EPA and ARB Commingling Evaluations

Upon comparing the ARB and the U.S. EPA commingling analysis, staff observed several key differences in both methodology and use of data. These differences result in contrasting conclusions between the two analyses.

A distinct difference between the two analyses is in the way brand-loyal consumers, those who always purchase one brand of gasoline, are handled. Staff assumed no or negligible commingling effects from this group of consumers. In contrast, the U.S. EPA assumed the group would contribute to commingling.

For input data that are a function of future market provisions, staff relied on the most up-to-date and reliable sources. Except for ethanol purchase propensity, both analyses shared similar information. For example, staff adopted ethanol market penetration from a study under the U.S. EPA contract.

Both the ARB and the U.S. EPA had access to consumer fueling habits information that, while obtained from different sources, was quite similar. However, the handling of these data was very different between the ARB and the U.S. EPA. ARB staff took precautionary steps to verify that these data were representative to population, and compared them to reliable sources for accuracy. However, the U.S. EPA, apparently based on its own judgment of what might possibly occur, modified the data.

These modifications produced lower brand loyalty, lower percent of fillup, and higher initial fuel tank levels than used by the ARB staff. Each of these modifications leads to a higher commingling effect. ARB staff believes that the data collected in their field study conclusively demonstrates that the use of modified data by U.S. EPA does not represent fueling habits in California, and produced an over estimation of the commingling analysis for the state. As a result, the U.S. EPA's analysis is fundamentally flawed, and the conclusions are questionable[7].

Because of these factors, the U.S. EPA's analysis has resulted in a 0.1 to 0.3 psi range of RVP increases from commingling in the South Coast air basin, with 0.2 psi RVP chosen as the likely commingling impact (see Appendix Q). Given the field observations now available and an improved simulation model, staff believes that the U.S. EPA has grossly overestimated the potential commingling impacts by, at least, a factor of two.

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[7] A similar conclusion was reached in an analysis produced by Systems Applications International ("Analysis of Commingling Due to Ethanol Blends"). In that analysis, the validity of the U.S. EPA analysis was questioned. This analysis, using the same model, but inputting the actual U.S. EPA data instead (i.e., unmodified), concluded that using the modified data would result in commingling impacts approximately twice as high as what it would have been using the actual data. A copy of this analysis is provided in Appendix P.

Appendix A:

Working Group

Air Resources Board
CaRFG3 Commingling Study Working Group

NAME	COMPANY
Bruce Heine	Williams
Cal Hodge	A 2nd Opinion, Inc.
Chuck A. Le Tavec	BP
Dennis Lamb	DWL Services
Duong Trinh	ARB
Ellen Shapiro	Auto Alliance
Erik White	ARB
Fred Schmidt	ARB
Gary Whitten	ICF Consulting
Gina Grey	WSPA
Jim Uihlein	BP
John Freel	Chevron
Loren Beard	Daimler Chrysler
Micheal Okafor	ARB
Mike Ingham	Chevron
Neil Koehler	Kinenergy
Nelson Chan	ARB
Raak Veblen	ARB
Ramesh Ganeriwal	CEC
Steve Smith	Tosco Corp.
Thomas Eveland	Atty
Tom Koehler	Celilo Group

Appendix B:

Working Group Comments on Preliminary Draft Assessment

Major Comments from the Working Group and Peer Reviewer

On the ARB's Commingling Study

Date	Organization	Comment	Staff Comment / Action
4/9/2002	A 2nd Opinion, Inc. (Cal Hodge)	- Nothing substantial	- None
4/24/2002	Valero (Simone Yuan-Newman)	- Fuel weathering effect on commingling	- Field data are inconclusive - Low initial tank level so weathering may not play a major role
		- The adequacy of 5% tank 'heel' assumption	- A CRC study by SwRI (Aug. 2002) conforms that on average tank heel is about 5.2%
4/24/2002	Chevron (Lew Gibbs)	- Vehicle age distribution in 3 regions	- They are similar
		- Plot final RVP vs. dispensed RVP	- Will be added in the final report
		- Fuel weathering effect on commingling, especially in the Lake Tahoe area	- Same as above
		- Plot initial fuel tank level by region	- Will be added in the final report
		- The adequacy of 5% tank 'heel' assumption	- Same as above
5/7/2002	ExxonMobil (Craig P. Knoeller)	- CARB has overestimated the statewide commingling impacts by assuming that ethanol market penetration would be uniform throughout the state	- Will make adjustment to the analysis when information on fuel distribution constraints, under a waiver scenario, become more available
4/25/2002	UC, Berkeley (Rob Harley)	Fist Part: Field Study	
		- Avoid using 'statewide' term in commingling analysis, but focus more on urban areas (SF, LA)	- Will add more discussion to clarify the meaning of 'statewide' commingling impact, and add urban area analysis (LA) to address the U.S. EPA denial
		- Plot initial fuel tank level by region	- Same as above
		- Use 'quantitative' analysis of commingling	- Will include it as an addition or

Appendix C:

Fuel Sampling Protocol

CaRFG3 Commingling Study – Fuel Sampling Protocol

I. Introduction

In adopting the regulations for California Phase 3 reformulated gasoline (CaRFG3) by way of Resolution 99-39, the Board directed staff to further evaluate the expected real-world emissions impact of commingling CaRFG3 containing ethanol with CaRFG3 not containing ethanol in motor vehicle fuel tanks. Because as little as two volume percent ethanol in gasoline will raise its Reid vapor pressure (RVP) by about one pound per square inch (psi), commingling may result in increased evaporative motor vehicle emissions. The extent of commingling and its impact on evaporative emissions depends on several factors, including whether the federal reformulated gasoline year-round minimum oxygen requirement will continue to apply in California, refiner choices regarding the mix of oxygenated and non-oxygenated gasoline in a given area, and customer choices regarding brand and grade loyalty.

II. Field Study Overview

One aspect to be incorporated into the evaluation is a field study of the actual impacts of commingling fuels in vehicle fuel tanks. It is anticipated that this field study will be conducted at retail gasoline facilities in the Los Angeles, San Francisco, and Lake Tahoe areas of California. Sampling will be performed by teams consisting of three members each, with three teams deployed at three different stations on any given day. Teams will spend a minimum of one day at each station identified for participation in the study, two or three days in each geographical area. Although the actual time needed to draw a sample will be approximately 3 minutes, it is estimated that each team will be able to sample only about three vehicles per hour. Each team will likely collect about 35 fuel samples per day, resulting in between about 200 and 300 fuel samples generated per region. Vehicle fuel tank samples will be obtained from all customers willing to participate in the field study. The obtained fuel samples (including representative underground tank samples) will be analyzed for the fuel properties needed to evaluate the actual impact of commingling on vehicle evaporative emissions.

Fieldwork for this study will be conducted in two phases. The first phase, to be conducted in late June, was is to evaluate the efficacy of the draft fuel sampling protocol. Samples were will be taken from each of the service station's underground tanks upon arrival and departure at each test site. Vehicle fuel tank samples were will be obtained prior to refueling from all customers willing to participate. While the sampling and refueling operations were are taking place, the customers were will be interviewed to obtain information necessary for further evaluation. This information was will be recorded on field data sheets (sample attached) and will included a control number, sample identification numbers, date, time, year/make/model of vehicle, initial fuel gauge level, and amount (in gallons) and grade of product dispensed, and whether the customer had purchased a different brand of fuel within the last two refuelings. A second fuel sample was will be obtained from their vehicle tank after refueling. Experience gained in this first phase has been used to will determine if and how the draft sampling protocol could can be improved and finalized.

The second phase of fieldwork, to be conducted from early August July through late September August, will be the implementation of this the finalized sampling protocol. Samples will be taken from each of the service station's underground tanks upon arrival and departure at each test site. Vehicle fuel tank samples will be obtained prior to refueling from all customers willing to participate. While the sampling and refueling operations are taking place, the customer will be interviewed to obtain information necessary for further evaluation and to identify vehicles expected to have commingled fuel in their tank after refueling. This information will be recorded on field data sheets and will include a control number, sample identification numbers, date, time, year/make/model of vehicle, initial fuel gauge level, and amount (in gallons and dollars) and grade of product dispensed, and whether the customer had purchased a different brand of fuel within the last refueling. If an initial sample is successfully obtained from the vehicle fuel tank, a second fuel sample will be obtained from those vehicles expected to have commingled fuel in their tank after refueling. If an initial sample is not obtained from the vehicle fuel tank, a second fuel sample will not be taken. There will be two or three four different fuel samples that must be correctly identified and properly associated with each vehicle successfully tested.

Upon completion of the second phase of fieldwork, staff will evaluate the need to supplement the data with an additional focused study to better capture and characterize ethanol blends.

Samples from the vehicle tanks and the station's underground tanks will be obtained using American Society of Testing and Materials (ASTM) D 5842-95, "Standard Practice for Sampling and Handling of Fuels for Volatility Measurement". Vehicle tanks are not mentioned in the ASTM sampling method. However, we will be essentially following the tank tap portion of the sampling method using apparatus that the Air Resources Board (ARB) has successfully used for some time to obtain diesel samples from vehicle tanks to check for presence of red dye (see Section III.F for photos of apparatus). Special care will be taken to ensure that minimal evaporation takes place during the sampling process so that accurate RVP results will be obtained.

To minimize the amount of handling and the duration of sample storage prior to RVP analysis, samples will be analyzed for RVP in ARB's mobile laboratory that will be located in the general vicinity of the stations participating in the field study. This should enable the completion of most samples RVP analyses within 24 hours. All samples will be analyzed for RVP using ARB's "Test Method for the Determination of the Reid Vapor Pressure Equivalent Using an Automated Vapor Pressure Test Instrument" (see California Code of Regulation Title 13 §2297). All samples will subsequently be transported to ARB laboratory facilities in El Monte to be analyzed for the volumetric amount and type of oxygenate, as well as total oxygen content, by ASTM D 4815-94, "Standard Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C1 to C4 Alcohols in Gasoline by Gas Chromatography".

III. Sampling Protocol

A. Required Equipment

- 4-oz. clear glass sample bottles with lined plastic lids
- 1-liter aluminum sample bottles with foil lined plastic lids
- Polypropylene ¼ inch O.D. tubing
- ¼ inch x 25 ft. copper cooling coil
- 2 gal. round insulated water dispenser for cooling coil
- Ice & water
- Hand-operated vacuum pump
- Sample labels/Field data sheets
- Nozzle extension
- Sectioned boxes for 4-oz. bottle storage
- Ice chests for sample bottle conditioning and sample storage
- Cleanup and equipment maintenance supplies
- 16-20 oz. glass wash bottle
- Product rinse container (portable gas can)

B. Sampling Procedures

1) Vehicle Tank Sampling

A modified version of ASTM D 5842-95 will be used to obtain the vehicle fuel tank samples. While this method does not specifically address sampling from a vehicle fuel tank, the tank tap sampling procedure is being adapted to accommodate our specific needs. The sampling equipment is the same equipment that has been successfully used in ARB's ongoing program to sample vehicle fuel tanks to test for red dyed diesel fuel, with the addition of a copper cooling coil to condition the sample. Approximately 16 oz. of fuel will be removed from the vehicle tank for each 4-oz. sample obtained.

Prior to drawing each individual sample, the capped 4-oz. glass sample bottle will be chilled in an ice bath and preconditioned with the fuel to be sampled. To obtain the sample, a polypropylene sample line connected to the inlet of the cooling coil will be inserted into the vehicle's fuel fill pipe until it reaches product. The sampling apparatus will be flushed with product prior to obtaining the sample. A 16-20 oz. glass wash bottle will be connected to the hand-operated vacuum pump with the outlet end of the cooling coil inserted through the pump compression fitting into the bottom of the bottle. To adequately flush the sample line and cooling coil, approximately 10 oz. of fuel will be drawn through the apparatus into the wash bottle. The wash bottle will then be replaced with a clean, chilled, 4-oz. glass sample bottle and an additional 1 oz. of fuel will then be pumped into the sample bottle for preconditioning. The preconditioning fuel will then be discarded from the 4-oz. glass sample bottle and then poured into the wash container prior to obtaining the actual sample. All This wash material will be collected and disposed of according to the procedures described in Section E of this protocol. The sample will then be obtained by pumping additional fuel through the preconditioned apparatus. When the bottle is 70 to 85% full, it will be disconnected from the pump, capped, labeled, and stored in a cool location out of direct sunlight. All sample labels will include both the sample identification number and the unique control number associated with each participating sample vehicle. Care will be taken to minimize the amount of time the sample bottle is uncapped to avoid the potential for sample contamination from water condensation inside the bottle.

Samples containing visible water or other unusual contamination will not be considered valid for the purposes of this study and shall be disposed. Since the pump works on a vacuum principle, a negative pressure will be produced within the bottle. As a result, no product will touch the pump itself but instead will be drawn from the vehicle fuel tank through the sample line, through the cooling coil, and bottom-fill the 4-oz. glass sample bottle. If any product is accidentally drawn into the pump by overfilling or tipping the bottle, the pump will be disassembled, wiped down with a clean, dry shop towel, and air-dried prior to its next use.

2) Service Station Nozzle Sampling

ASTM D 5842-95 will be used to obtain samples from the service station's underground tanks for all grades dispensed at the station. Although this method allows the use of 4-oz. sample bottles, 1-liter sample bottles will be used due to their ease of use when obtaining a dispenser sample. The 1-liter sample bottles will be chilled in ice water prior to and while obtaining a sample. The bottle will be rinsed with product and drained before being bottom-filled with a nozzle extension attached to the service station dispenser nozzle. After the bottle is filled between 70 to 85% full, the bottle will be capped, labeled, and stored in a cool location out of direct sunlight. Care will be taken to minimize the amount of time the sample bottle is uncapped to avoid the potential for sample contamination from water condensation inside the bottle.

C. Sample Handling Procedures

It is essential that proper sample identification and field data sheet referencing is completed for each vehicle sample set. Preformatted Preprinted self-adhesive sample identification labels will be completed and attached to each sample bottle with each sample identification number also being recorded on the and corresponding field data sheet. Label ink and adhesive will be resistant to water and gasoline to assure identification integrity. Vapor pressures are extremely sensitive to evaporation loses and to slight changes in composition. Necessary precautions will be observed when handling samples to ensure the samples are representative of the product and satisfactory for RVP analysis.

D. Analytical Methods

Fuel samples obtained will be analyzed by the following methods:

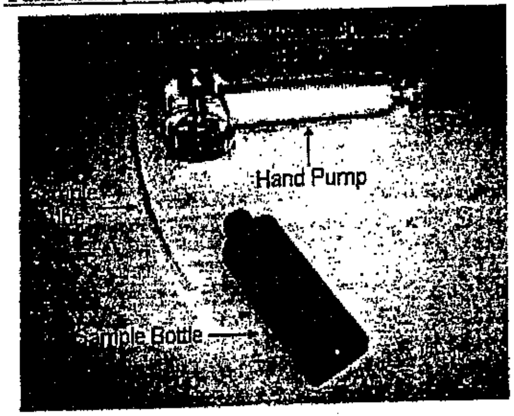
Fuel Quality	Analysis Method
RVP (psi)	CCR Title 13 §2297*
Oxygen Content (wt.%)	ASTM D 4815-94
MTBE (vol.%)	ASTM D 4815-94
Ethanol (vol.%)	ASTM D 4815-94

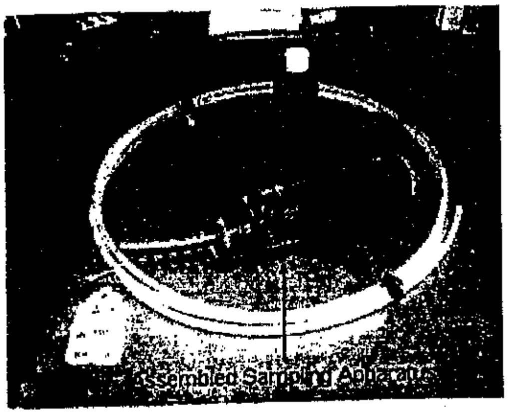
*Paragraph (d)(1.0) which specifies a Title 13 sampling method will be replaced with ASTM D 5842 sampling method which allows for the use of either 32-oz or 4-oz bottles.

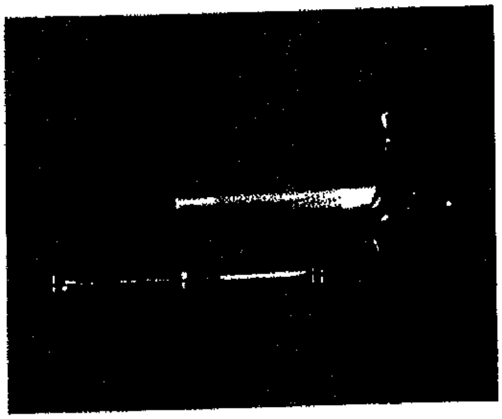
E. Disposal of Fuel Samples & Wash Materials

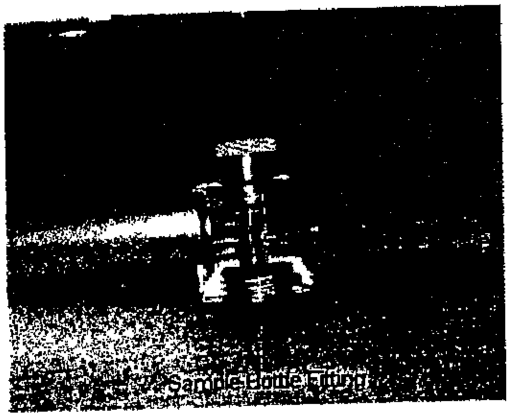
All waste gasoline generated from the sampling and analytical procedures will be collected in approved gasoline storage containers and disposed of at authorized gasoline recycling facilities.

F. Tank Sampling Apparatus

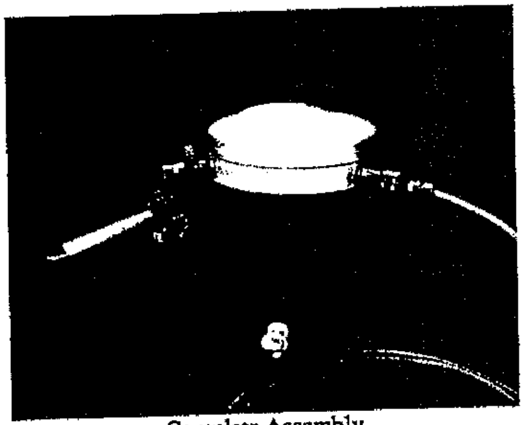









Interior View of Cooling Coil


Complete Assembly

FIELD DATA SHEET

CaRFG3 Commingling Study - Fuel Sampling Program

Date: ___________ Time: ________ Control No: ___________

Vehicle Information

Year: ___________________________ Make: ___________________________

Model: ___________________________ Fuel Gauge: E -------\-------|-------/------- F

1st Sample Obtained? Yes ___ No ___ Sample No: ______________________

Refueling Information

Brand: ___________ Grade: _______ Amount: $_______ & _______gal.

Was a different brand of gasoline used for the last refueling? Yes ___ No ___ ? ___

2nd Sample Obtained? Yes ___ No ___ Sample No: ______________________

Sampling Team Member: ______________________________________

(Certification from a team member that is not the custodian that the test was performed)

Customer's Name: ______________________________________

Customer's Signature: ______________________________________

(Required for accounting purposes. Signature acknowledges receipt of $5 payment for services.)

Script

Action	**Elapsed Time**
Customer enters station, is greeted by team member, and offered incentive for voluntary participation in study.	00:00.30
Team proceeds to obtain initial sample and vehicle information.	00:03.30
Customer refuels vehicle.	00:06.30
Team proceeds to obtain second sample, completes field data sheet.	00:09.30
Customer's signature is obtained in exchange for payment of incentive.	00:10.00

Appendix D:

Field Study Data Set

CaRFG3 Commingling Study Fuel Sampling Data

control no.	vehicle information				got 1^{st}	rvp^1	wt% O_2^1	volume %			refueling information						got 2^{nd}	rvp^2	wt% O_2^2	volume %			rvp^{am}	wt% O_2^{am}	volume %			rvp^{pm}	wt% O_2^{pm}	volume %		
	year	make	model	gage				eth^1	mtbe^1	tam^1	site	grd	cost	gal	fill	dif				eth^2	mtbe^2	tam^2			eth^{am}	mtbe^{am}	tam^{am}			eth^{pm}	mtbe^{pm}	tam^{pm}
LT1-01	2000	Saturn	SL2	E	1	6.87	2.06	0.00	11.31	0.00	no.1	R	16.80	10.53	1	1	1	6.96	2.21	5.06	1.79	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-02	1988	Subaru	DL	5/8	0						no.1	R	10.00	6.50	0	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-03	1990	Toyota	PU	E	1	6.48	0.45	0.04	2.22	0.00	no.1	R	23.42	15.22	1	1	1	6.87	2.01	5.16	0.52	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-04	2001	Chev	Lumina	3/4	0						no.1	R			1	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-05	1997	Honda	Civic CX	E	0						no.1	R	14.31	9.30	1	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-06	1986	Toyota	4Runner	1/4	1	7.18	0.56	0.89	1.09	0.00	no.1	R	5.00	3.25	0	1	1	7.61	1.25	2.98	0.79	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-07	1995	Ford	Explorer	1/8	1	7.09	1.65	4.30	0.29	0.00	no.1	R	26.26	17.07	1	0	1	6.85	2.11	5.56	0.25	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-08	1977	Dodge	Sprtsmn Vn	7/8	1	7.56	0.76	1.91	0.26	0.00	no.1	R	19.31	12.55	1	0	1	8.21	0.95	2.42	0.27	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-09	1997	Jeep	Cherokee	E	1	6.61	0.08	0.00	0.29	0.00	no.1	R	10.00	6.50	0	1	1	6.98	1.85	4.86	0.24	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-10	1997	Chev	Silverado PU	5/8	1	6.35	1.93	0.00	10.54	0.00	no.1	R	18.60	12.09	1	1	1	6.87	2.15	3.07	5.54	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-11	1973	Chev	1T PU	1/8	1	6.25	1.67	4.39	0.24	0.00	no.1	R	21.20	13.78	1	1	1	6.56	1.88	4.94	0.25	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-12	1996	Chev	1500 PU	E	1	6.72	1.95	5.08	0.35	0.00	no.1	R	33.70	21.90	1	0	1	6.76	2.26	5.97	0.25	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-13	1999	Dodge	Caravan	1/8	1	6.28	1.99	0.00	10.92	0.00	no.1	R	20.00	13.00	1	1	1	6.83	2.19	4.34	3.14	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-14	1999	Toyota	Tacoma PU	E	1	6.87	1.48	3.85	0.25	0.00	no.1	R	10.00	6.50	0	1	1	6.73	2.23	5.90	0.25	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-15	1999	Mitsubishi	Mirage	1/2	1	6.63	1.68	0.38	7.82	0.70	no.1	P	7.77	4.47	1	1	1	6.90	1.82	2.29	4.93	0.46	6.70	2.09	5.50	0.25	0.00	6.66	2.08	5.48	0.25	0.00
LT1-16	1993	VW	Eurovan	1/4	1	6.28	1.02	0.00	5.57	0.00	no.1	R	22.77	14.80	1	1	1	6.98	1.89	4.18	1.84	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-17	1990	Lincoln	Towncar	1/4	1	6.83	1.97	5.30	0.00	0.00	no.1	R	17.06	11.08	1	1	1	6.74	2.17	5.74	0.23	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-18	1977	Jeep	CJS	E	0						no.1	R	26.08	16.95	1	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-19	2001	Toyota	4Runner	E	1	6.24	1.74	0.00	9.53	0.00	no.1	R	26.01	16.90	1	1	0						6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-20	2000	Jeep	Cherokee	1/8	1	6.11	0.07	0.03	0.34	0.00	no.1	R	10.00	6.50	0	1	1	6.95	1.76	4.60	0.27	0.00	6.72	2.26	5.98	0.23	0.00	6.79	2.28	6.02	0.23	0.00
LT1-21	2000	Ford	Expedition	1/4	0						no.2	R	32.65	18.15	1	0	0						6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-22	1989	Jeep	Cherokee	E	1	6.93	0.05	0.00	0.29	0.00	no.2	R	4.77	2.65	0	1	1	6.53	0.06	0.00	0.31	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-23	1988	Ford	F250 PU	E	1	6.16	0.62	0.00	3.37	0.00	no.2	M	13.00	5.70	0	0	1	6.45	0.27	0.00	1.47	0.00	6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-24	1991	Mercedes	500SL	E	1	6.56	1.87	0.00	10.24	0.00	no.2	P	37.15	18.40	1	0	1	6.38	0.28	0.00	1.53	0.00	6.28	0.05	0.00	0.25	0.00	6.27	0.04	0.00	0.24	0.00
LT1-25	2000	GMC	Jimmy	1/4	1	6.74	0.14	0.00	0.57	0.00	no.2	R	6.01	3.34	0	?	1	6.76	0.09	0.00	0.48	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-26	1989	Chev	Blazer	1/4	1	6.4	0.05	0.00	0.28	0.00	no.2	M	20.03	10.38	0	0	1	6.48	0.05	0.00	0.29	0.00	6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-27	1993	Jeep	Cherokee	E	1	6.61	2.00	0.53	9.24	0.70	no.2	R	10.00	5.56	0	1	1	6.70	0.57	0.10	2.79	0.14	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-28	2002	Mercedes	C320 Spfwgn	1/4	0						no.2	M	22.07	11.44	1	1	0						6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-29	2000	Chrysler	Concorde	1/4	0						no.2	R	20.25	11.26	1	0	0						6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-30	1997	Ford	Contour	E	1	6.89	0.24	0.04	1.04	0.24	no.2	R	6.17	3.43	0	0	1	6.73	0.12	0.00	0.64	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-31	2001	Lexus	ES300	1/8	0						no.2	M	27.38	14.19	1	0	0						6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-32	1967	GMC	PU	1/8	1	6.43	0.33	0.00	1.82	0.00	no.2	R	17.65	9.81	0	0	1	6.56	0.14	0.00	0.79	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-33	1999	Ford	Ranger PU	E	0						no.2	R	25.38	14.11	1	1	0						6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-34	2000	VW	Passat	1/4	0						no.2	M	21.79	10.79	1	1	0						6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-35	1987	Saab		E	1	6.25	0.22	0.00	1.19	0.00	no.2	R	10.00	5.56	0	1	1	6.45	0.12	0.00	0.67	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-36	1985	Audi	4000S	E	1	6.41	1.27	0.00	5.62	1.61	no.2	R	10.00	5.56	0	1	1	6.56	0.37	0.00	1.69	0.35	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-37	1996	Dodge	Caravan	5/8	1	6.72	0.25	0.00	1.39	0.00	no.2	R	12.98	7.22	1	0	1	6.69	0.19	0.00	1.02	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00

CaRFG3 Commingling Study Fuel Sampling Data

control no.	vehicle information				got 1^{st}	rvp^1	wt% O$_2^1$	volume %			refueling information						got 2^{nd}	rvp^2	wt% O$_2^2$	volume %			rvp^{am}	wt% O$_2^{am}$	volume %			rvp^{pm}	wt% O$_2^{pm}$	volume %		
	year	make	model	gage				eth^1	mtbe^1	tam^1	site	grd	cost	gal	fill	dif				eth^2	mtbe^2	tam^2			eth^{am}	mtbe^{am}	tam^{am}			eth^{pm}	mtbe^{pm}	tam^{pm}
LT1-38	1998	GMC	Sonoma	E	1	6.86	0.09	0.00	0.29	0.00	no.2	M	29.00	15.03	1	1	1	6.63	0.05	0.00	0.30	0.00	6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-39	1998	Subaru	Outback	E	1	6.44	0.09	0.00	0.33	0.00	no.2	M	24.98	12.95	1	1	1	6.60	0.05	0.00	0.29	0.00	6.63	0.05	0.00	0.28	0.00	6.54	0.05	0.00	0.27	0.00
LT1-40	1993	Isuzu	Trooper	E	1	6.5	0.07	0.00	0.39	0.00	no.2	R	19.92	11.08	0	0	1	6.60	0.06	0.00	0.32	0.00	6.60	0.06	0.00	0.33	0.00	6.63	0.06	0.00	0.32	0.00
LT1-41	2001	Ford	150 PU	E	1	6.8	0.91	2.33	0.24	0.00	no.3	R	15.00	9.56	0	1	1	6.99	1.75	4.60	0.21	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-42	2001	Volvo	S80	1/4	0						no.3	R	18.49	11.78	1	1	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-43	1971	Chev	Blazer	3/4	1	6.93	1.79	4.71	0.22	0.00	no.3	R	8.35	5.32	1	1	1	6.89	1.78	4.80	0.00	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-44	1992	Mercury	Sable	5/8	1	6.44	1.89	0.00	10.36	0.00	no.3	R	10.00	6.37	1	1	1	6.90	1.88	2.14	5.93	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-45	1999	Cadillac	DeVille	3/4	1	6.53	2.01	2.49	5.93	0.00	no.3	P	13.00	7.35	0	1	1	6.70	2.03	3.42	4.15	0.00	6.80	2.09	5.46	0.36	0.00	6.79	2.09	5.48	0.33	0.00
LT1-46	1999	Hyundai	Elantra	1/4	0						no.3	R	10.00	6.37	0	1	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-47	2001	Chrysler	T&C Van	1/2	1	6.4	1.54	0.00	8.44	0.00	no.3	R	18.00	11.47	1	1	1	6.96	1.79	3.20	3.30	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-48	1993	Mercury	Grd Marquis	1/4	1	6.31	1.84	0.00	10.07	0.00	no.3	R	20.48	13.05	1	1	1	6.96	1.87	3.04	4.08	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-49	1987	Hyundai	Excel	1/4	1	6.79	2.07	5.46	0.24	0.00	no.3	R	10.00	5.99	0	0	1	6.87	2.06	5.42	0.28	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-50	1979	Toyota	PU	E	1	6.82	1.91	3.11	3.90	0.29	no.3	R	10.00	6.37	0	1	1	6.87	1.99	4.87	0.97	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-51	2001	Dodge	Caravan	3/8	1	6.22	1.90	0.05	9.98	0.38	no.3	R	21.01	13.39	1	1	1	6.90	1.94	3.83	2.85	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-52	1995	Toyota	Corolla	3/8	0						no.3	R	12.24	7.80	1	0	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-53	1998	Chev	1500 PU	1/4	0						no.3	R	35.00	22.31	1	1	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-54	2001	Ford	Taurus	1/4	0						no.3	R	16.50	10.52	1	1	0						6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-55	1985	Toyota	PU	1/8	1	7.54	0.61	1.42	0.29	0.00	no.3	R	10.00	6.37	0	0	1	7.22	1.25	3.26	0.24	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-56	1984	Nissan	Maxima	1/8	1	7.31	0.39	0.91	0.27	0.00	no.3	M	20.41	12.20	1	0	1	6.99	1.66	4.35	0.27	0.00	6.79	2.09	5.46	0.35	0.00	6.92	2.06	5.40	0.27	0.00
LT1-57	1993	Toyota	PU	1/8	1	6.76	0.39	0.20	1.73	0.00	no.3	R	10.00	6.37	0	1	1	7.09	1.55	3.85	0.66	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-58	1993	Lincoln	Towncar	3/8	1	6.72	1.96	4.68	1.23	0.00	no.3	R	17.03	10.86	1	0	1	6.86	1.97	5.00	0.65	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-59	1991	Mercury	Topaz	E	1	6.93	1.34	3.44	0.26	0.00	no.3	R	5.00	3.19	0	1	1	6.92	1.69	4.44	0.21	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT1-60	1993	Ford	Ranger PU	E	1	6.25	0.07	0.00	0.30	0.00	no.3	R	27.80	17.72	1	1	1	6.95	1.66	4.36	0.21	0.00	6.98	2.03	5.36	0.22	0.00	6.92	2.00	5.38	0.00	0.00
LT2-01	1998	Dodge	Durango	7/8	1	7.01	2.08	2.49	6.12	0.22	no.4	M	10.00	6.10	1	1	1	7.06	1.59	1.87	4.77	0.17	6.43	0.06	0.00	0.34	0.00	6.44	0.06	0.00	0.30	0.00
LT2-02	1992	Honda	Accord	1/4	0						no.4	R	8.00	5.20	0	1	0						6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-03	1983	Dodge	Ram PU	E	1	6.51	1.06	0.00	5.80	0.00	no.4	R	6.01	3.91	0	0	1	6.57	0.56	0.00	3.09	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-04	1991	Nissan	Pathfinder	1/8	1	6.67	0.12	0.00	0.52	0.00	no.4	R	25.32	16.45	1	1	1	6.60	0.08	0.00	0.41	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-05	1995	Chevy	Astro	1/4	1	6.45	2.00	0.00	10.59	0.00	no.4	R	7.00	4.55	0	1	1	6.50	1.29	0.00	6.90	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-06	1998	Ford	Escort	1/4	0						no.4	R	10.00	6.50	0	1	0						6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-07	1999	Chevy	Astro	1/4	1	6.47	2.04	0.00	10.29	1.00	no.4	R	22.23	14.45	1	1	1	6.56	0.82	0.00	4.14	0.41	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-08	1993	Chevy	1500 PU	1/8	1	8.01	0.07	0.00	0.36	0.00	no.4	R	31.33	20.34	1	0	1	6.87	0.07	0.00	0.37	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-09	1991	Dodge	Shadow	1/4	1	6.74	2.19	0.00	9.20	0.00	no.4	R	11.45	7.44	1	1	1	6.87	0.90	0.00	3.95	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-10	1978	Toyota	PU	1/2	1	6.64	2.01	0.00	11.04	0.00	no.4	R	12.50	8.12	1	1	1	6.69	1.05	0.00	5.77	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-11	2001	Toyota	Avalon	1/4	0						no.4	R	19.25	12.51	1	1	0						6.56	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-12	1994	Ford	Ranger	1/4	1	6.61	0.06	0.00	0.31	0.00	no.4	R	10.00	6.50	0	1	1	6.64	0.07	0.00	0.36	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-13	2000	Dodge	Intrepid	1/2	0						no.4	R	13.49	8.77	1	1	0						6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00
LT2-14	1997	Toyota	Tacoma	E	1	6.87	2.04	0.00	1.82	0.00	no.4	R	10.00	6.50	0	1	1	7.28	0.60	0.00	0.81	0.00	6.58	0.07	0.00	0.40	0.00	6.63	0.08	0.00	0.42	0.00

ONROAD VEHICLES

Area	*OLD RVP*	*VOC Tons/Day*	*NEW RVP*	*VOC Tons/Day*	*Tons/Day INCREASE*	*Degradation INCREASE*	*Tons/Day Total*
NYMA	6.7	192.9	7.0	198.7	5.8	2.7	8.5
NYMA	6.7	192.9	7.7	211.4	18.5	2.7	21.2
Upstate	8.3	297.3	8.6	306.8	9.5	8.7	18.2
Upstate	8.3	297.3	9.3	337.5	40.2	8.7	48.9

NONROAD VEHICLES

Area	*OLD RVP*	*VOC Tons/Day*	*NEW RVP*	*VOC Tons/Day*	*Tons/Day INCREASE*
NYMA	6.7	172.2	7.0	173.3	1.1
NYMA	6.7	172.2	7.7	176.1	3.9
Upstate	8.3	313.2	8.6	315.6	2.4
Upstate	8.3	313.2	9.3	321.9	8.7

Total Ethanol Increases in tons/day

If there is an increase of 0.3 psi Statewide	**30.2**
If there is an increase of 0.3/1.0 psi in RFG/Conventional areas	**67.2**
If there is an increase of 1.0 psi Statewide	**82.7**

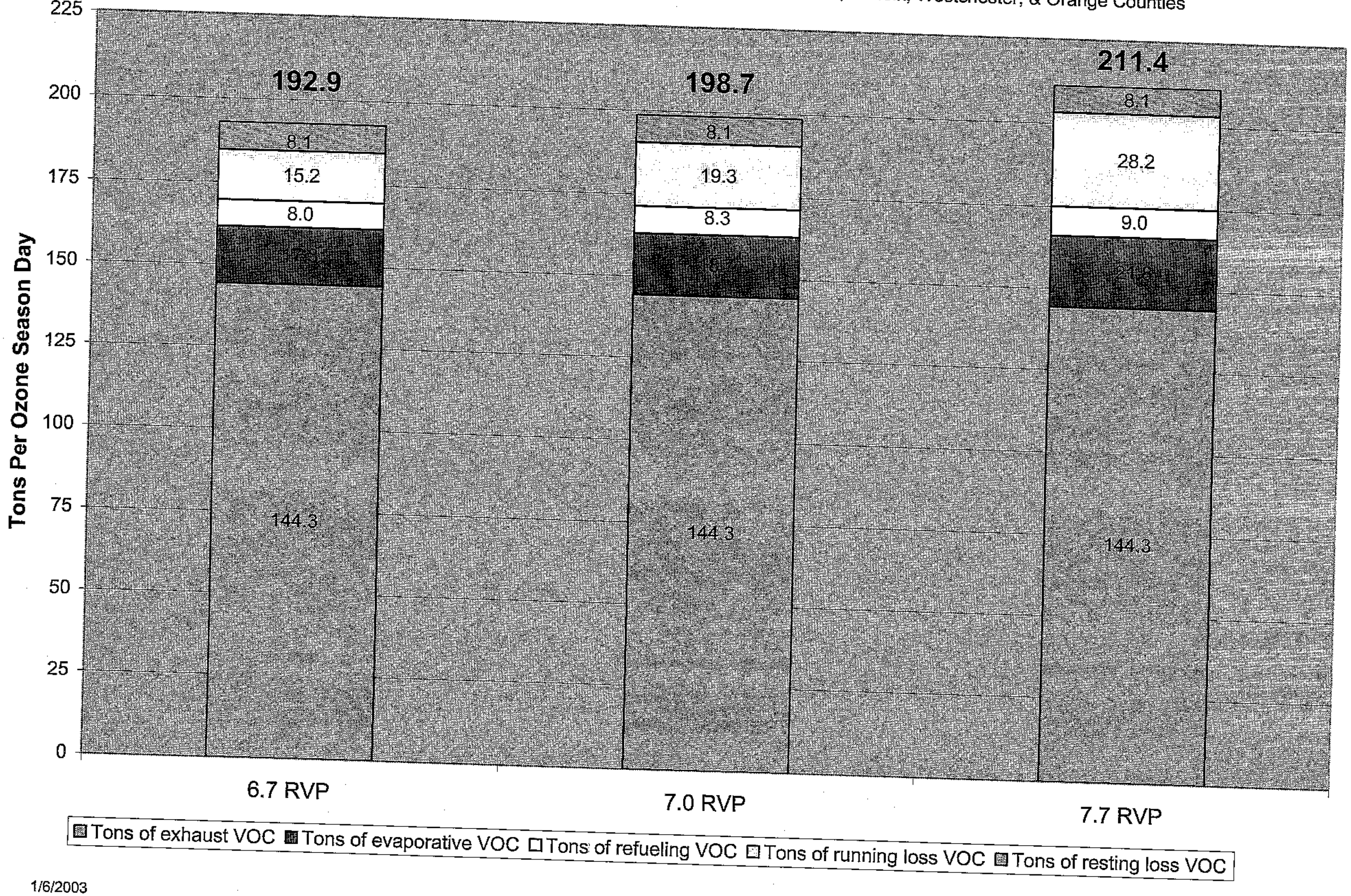
* Nonroad estimates from the NONROAD model, Onroad emission estimates from DECLEV2

** Ethanol increases based on California estimates from an unknown report.

NYMA On-Road VOC Emissions at 6.7, 7.0 & 7.7 RVP

* Emission Estimates Run Using DECLEV2 Which Accounts For LEV2 Without Sulfur Corrections

** NYMA Includes Bronx, Kings, Nassau, New York, Queens, Richmond, Rockland, Suffolk, Westchester, & Orange Counties



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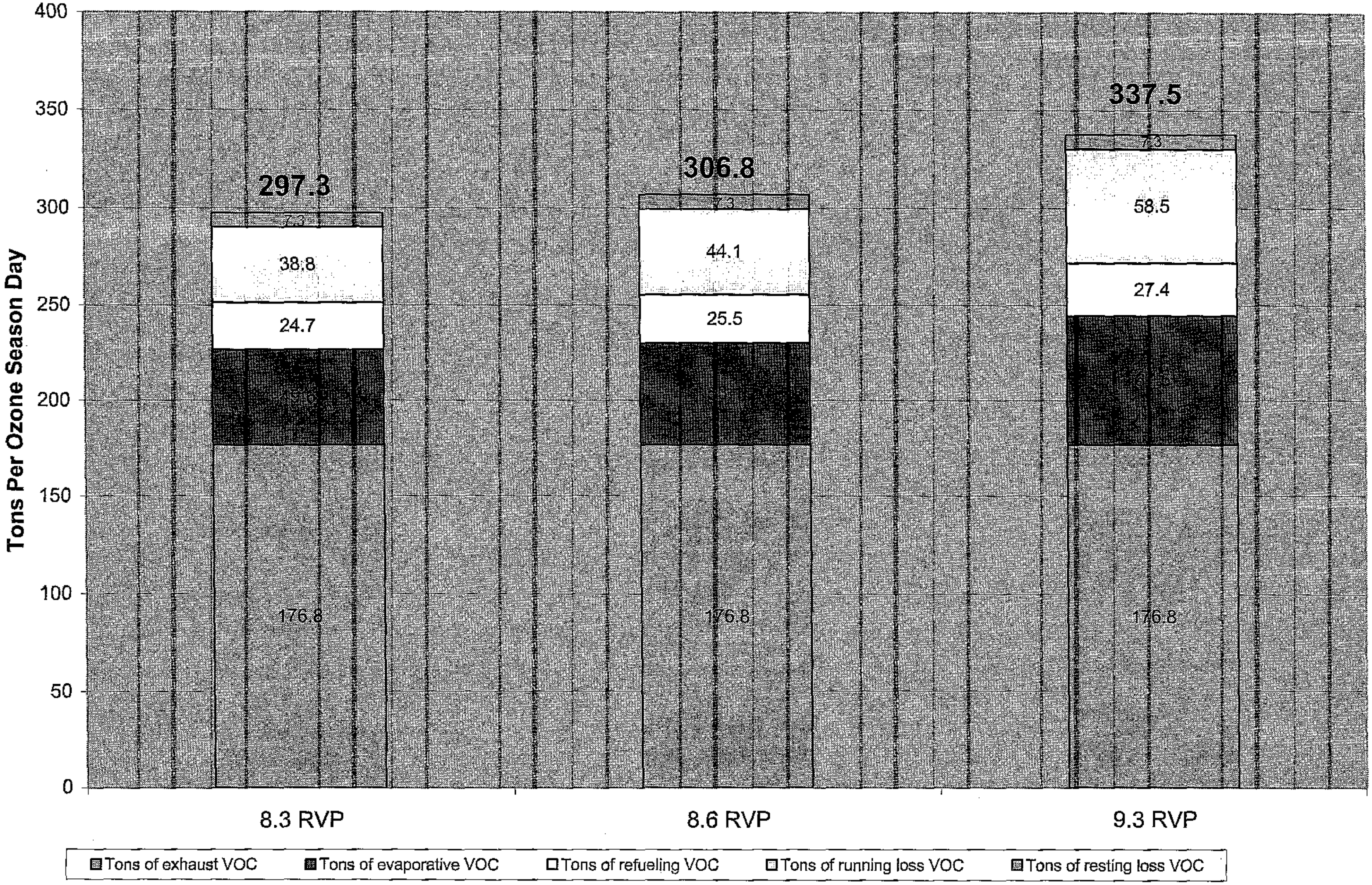
BAQP - MSS

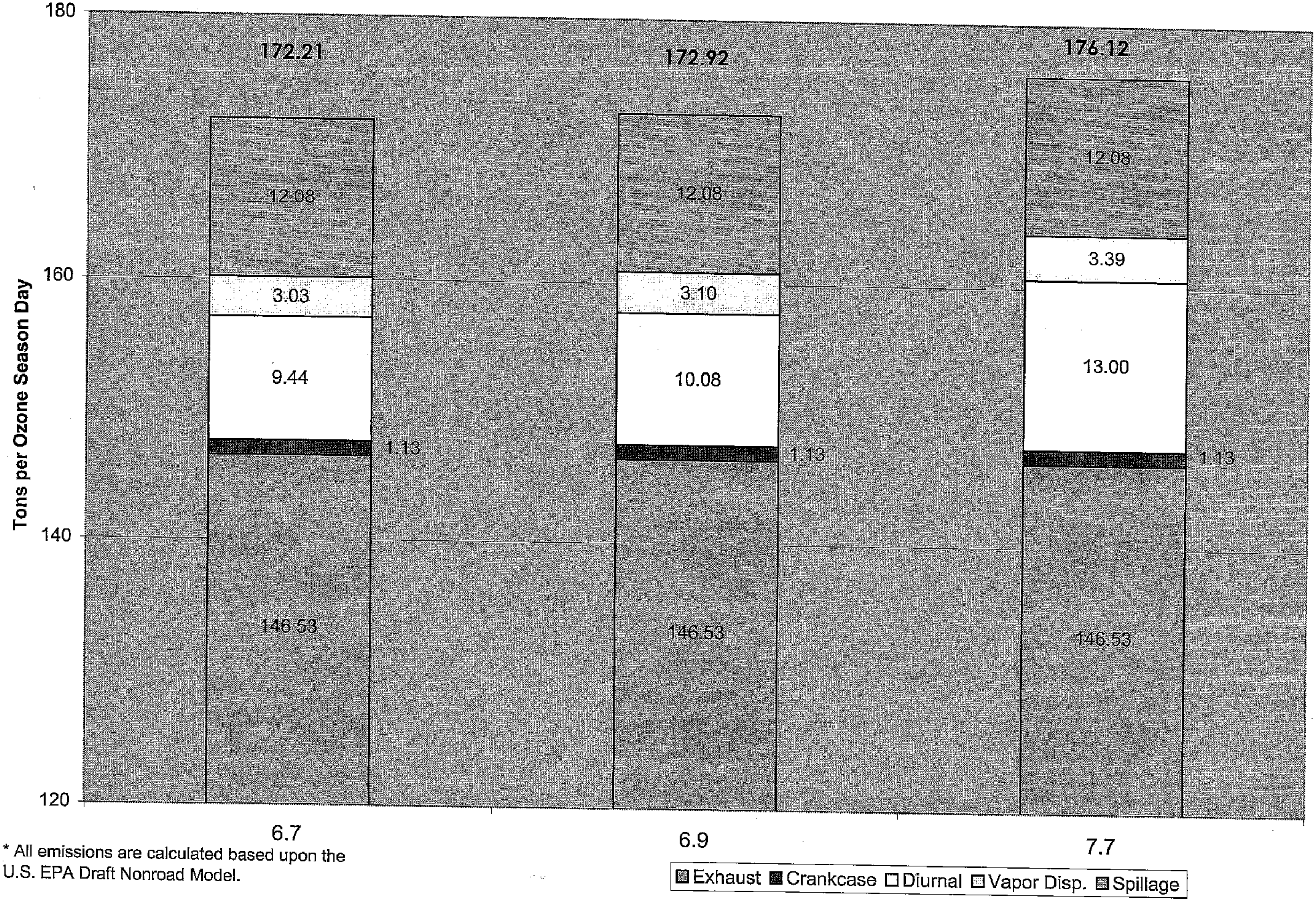
RVP_changes2.xls

Upstate NY On-Road VOC Emissions At 8.3, 8.6 & 9.3 RVP

*** Emission Estimates Run Using DECLEV2 Which Accounts For LEV2 Without Sulfur Corrections.**

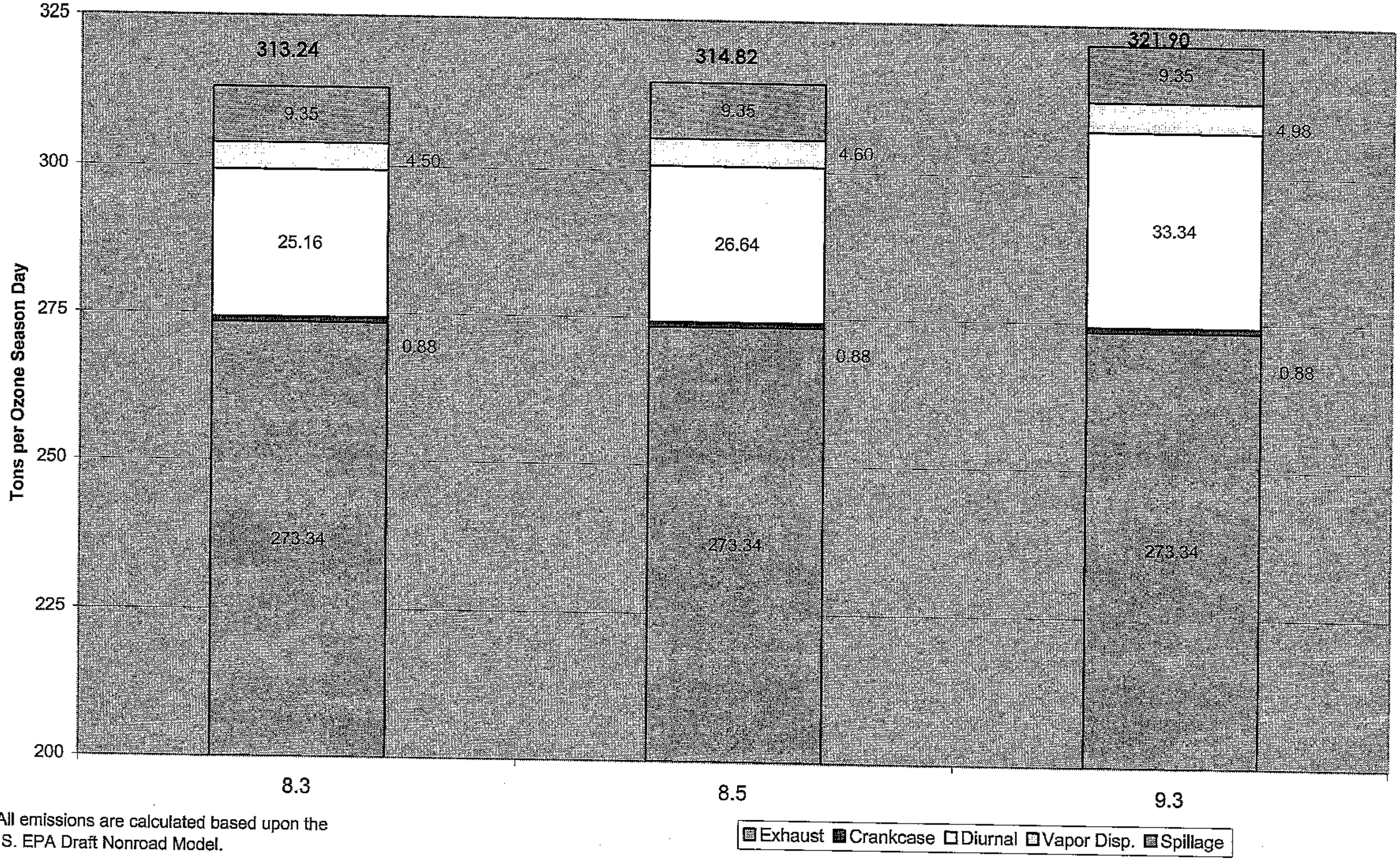


2007 Downstate NY VOC Emissions at 6.7, 6.9 and 7.7 RVP



* All emissions are calculated based upon the U.S. EPA Draft Nonroad Model.

2007 Upstate NY VOC Emissions at 8.3, 8.5 and 9.3 RVP



* All emissions are calculated based upon the U.S. EPA Draft Nonroad Model.

U.S. DISTRICT COURT – N.D. OF N.Y.
FILED
[illegible] 2003
AT ______ O'CLOCK ______
Lawrence K. Baerman, Clerk - Syracuse

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF NEW YORK

◆◆◆

OXYGENATED FUELS ASSOCIATION, INC.
Plaintiff,

-v-

1:00-CV-1073

GEORGE PATAKI, in his capacity as Governor of the State of New York, and ELIOT SPITZER, in his capacity as Attorney General for the State of New York,
Defendants.

◆◆◆

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Norman A. Mordue, D.J.:

MEMORANDUM-DECISION AND ORDER

Plaintiff is a trade association, the members of which include major producers of methyl tertiary butyl ether ("MTBE"), an oxygenated fuel additive ("oxygenate") used in motor vehicle fuel to improve combustion for the purpose of reducing emissions pollution. In this action under the Supremacy Clause, U.S. CONST., Art. VI, cl. 2, the Clean Air Act ("CAA"), 42 U.S.C. § 7401 *et seq.*, and the Civil Rights Act, 42 U.S.C. § 1983, plaintiff challenges the constitutionality of a New York law ("N.Y. MTBE Law") prohibiting the use, sale, or importation in New York of gasoline containing MTBE beginning January 1, 2004. Plaintiff seeks judgment declaring that New York MTBE Law is preempted by CAA and regulations promulgated thereunder and thus is unconstitutional under the Supremacy Clause of the United States Constitution. U.S. CONST. art. VI, cl. 2.

The Court assumes familiarity with the earlier decisions in this case. *See Oxygenated Fuels Ass'n, Inc. v. Pataki*, 158 F.Supp.2d 248 (N.D.N.Y. 2001) ("*OFA v. Pataki*"); as amended on reconsideration by Memorandum-Decision and Order of May 16, 2002; motion for certification to Second Circuit denied by Memorandum-Decision and Order of December 6, 2002; defendants' motion for dismissal and plaintiff's cross-motion for summary judgment denied by Memorandum-Decision and Order of October 3, 2003.

The Court held a bench trial on October 8, 9, 10, 14, 15 and 23, 2003. For reasons set forth herein, the Court finds that plaintiff has not proven its case and awards judgment in favor of defendants dismissing the case in its entirety.

BACKGROUND

Complaint

In its complaint, filed July 11, 2000, plaintiff claims that N.Y. MTBE Law violates the Supremacy Clause because it legislates in a field preempted by Congress, and that it violates plaintiff's civil rights under 42 U.S.C. § 1983. Plaintiff seeks judgment declaring that the law is invalid because, in CAA and the regulations promulgated thereunder, Congress and the Environmental Protection Agency ("EPA") expressly preempted legislation in the field of fuel and fuel additives for whatever purpose; because Congress impliedly preempted that field; and because N.Y. MTBE Law is "conflict-preempted" by CAA, that is, N.Y. MTBE Law would be an obstacle to the accomplishment and execution of the full purposes and objectives of Congress in CAA. Plaintiff further seeks injunctive relief prohibiting New York from taking any steps to implement or enforce N.Y. MTBE Law and from taking any future action to ban the use of MTBE in gasoline in New York.

Issue at trial

In denying plaintiff's motion for summary judgment on May 18, 2001, the Court held that N.Y. MTBE Law was not expressly or impliedly preempted by federal law. *See OFA v. Pataki*, 158 F. Supp. 2d at 255, 257-58. The Court further held that the issue of conflict preemption could not be determined on the record before the Court and must be tried. *See id.* at 258. Accordingly, the Court held a bench trial on October 8, 9, 10, 14, 15 and 23, 2003, on the sole issue of conflict preemption.

CAA and the RFG program

The stated purpose of CAA is "to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." CAA § 101(b)(1), 42 U.S.C. § 7401(b)(1). In furtherance of this purpose, Congress enacted the reformulated gasoline ("RFG") program in 1990, CAA § 211(k), 42 U.S.C. § 7545(k), to address ozone pollution in areas which have failed to attain National Ambient Air Quality Standards ("NAAQS") for ground-level ozone ("nonattainment areas").

The RFG program requires the sale in nonattainment areas of RFG, *i.e.*, gasoline having certain properties, for the purpose of reducing ozone-causing exhaust and evaporative emissions. *See* CAA § 211(k)(2), (5).

The RFG legislation directs EPA to "promulgate regulations ... establishing requirements for reformulated gasoline to be used in gasoline-fueled vehicles" in nonattainment areas, CAA § 211(k)(1), and sets forth detailed requirements that EPA must include in its regulations. CAA § 211(k)(2), (3). One such requirement is an oxygen content of at least two percent, CAA § 211(k)(2)(B), which is obtained by the addition of oxygenates such as MTBE or ethanol. The statute empowers EPA to determine which fuels may be sold in nonattainment areas and prohibits the sale or dispensing of all other fuels in those areas. CAA § 211(k)(4), (5). EPA may prescribe sampling, testing and record-keeping requirements and impose penalties, CAA § 211(d), (k)(5), and may adjust or waive requirements of the program under certain circumstances. CAA § 211(k)(2)(A), (B), (D). Section 211(c)(1) authorizes EPA to control or prohibit the sale of any fuel or fuel additive if in its judgment any emission product of that fuel or fuel additive causes or contributes to air pollution which may endanger public health or welfare. State regulation of any component or characteristic of a fuel or fuel additive for purposes of emissions control is proscribed except with EPA approval under narrowly defined circumstances. CAA § 211 (c)(4)(A)(i), (ii).

N. Y. MTBE Law

It is undisputed that MTBE has a great affinity for water, that it has been detected in groundwater in New York state, and that its taste and odor can be perceived at very low levels. New York enacted N.Y. MTBE Law on May 24, 2000, by amending N.Y. Agriculture and

Markets Law (L.2000, c. 35, § 2) to add section 192-g, which provides:

> 1. For the purposes of this section, "gasoline" shall mean any fuel sold for use in motor vehicles and motor vehicle engines, and commonly or commercially known or sold as gasoline.
> 2. No person shall import into, or sell, dispense or offer for sale any gasoline which contains methyl tertiary butyl ether.
> 3. Any person who violates the provisions of this section shall be liable for a civil penalty of not less than five hundred dollars nor more than ten thousand dollars.

New York also amended section 19-0301(3) of N.Y. Environmental Conservation Law (L.2000, c. 35, § 2) to add a new subsection B, which states: "No provision of this subdivision shall be deemed to authorize the use of methyl tertiary butyl ether as an oxygenate in any motor fuel imported into, or sold or offered for sale in this State." The amendments are effective January 1, 2004 (L.2000, c. 35, § 3). That the purpose of the N.Y. MTBE Law is to protect New York's groundwater from contamination is not seriously contested by plaintiff.

DISCUSSION

The sole issue before the Court is whether N.Y. MTBE Law is "conflict-preempted" by federal law. Conflict preemption occurs when "compliance with both federal and state regulations is a physical impossibility," *Florida Lime & Avocado Growers, Inc. v. Paul*, 373 U.S. 132, 142-43 (1963), or when state law "stands as an obstacle to the accomplishment and execution of the full purposes and objectives of Congress." *Hines v. Davidowitz*, 312 U.S. 52, 67 (1941). Courts must narrowly construe a federal law which is claimed to preempt an exercise of state police power. *See Cipollone v. Liggett Group, Inc.*, 505 U.S. 504, 518 (1992). Indeed, when Congress legislates in a field traditionally within the police powers of the states, such as matters related to public health and safety, there is a presumption that the state law is not invalidated under the Supremacy Clause. *See Hillsborough Co. v. Automated*

Med. Labs., Inc., 471 U.S. 707, 715 (1985).

It is undisputed that N.Y. MTBE Law, which has the purpose of protecting New York's groundwater from contamination, is a proper exercise of New York's police power to regulate and control matters related to public health and safety. *See id.* Accordingly, in considering plaintiff's claim that N.Y. MTBE Law is preempted, the Court must narrowly construe CAA and must bear in mind the presumption that the state law is not preempted.

The stated purpose of CAA is "to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." CAA § 101(b)(1). Thus, enhancement of air quality is clearly the overriding goal of CAA. In the Court's view, however, evidence that a state law would have a relatively minor impact on air quality would be insufficient to support a finding that it stands as an obstacle to the accomplishment and execution of the full purposes and objectives of CAA.

In defining the goal of CAA specifically with reference to the RFG program,[1] this Court stated that "the congressional goal in enacting the RFG program was to reduce emissions pollution while ensuring an adequate gasoline supply at a reasonable cost, taking into account other health and environmental concerns so far as reasonable." *OFA v. Pataki*, 158 F. Supp.2d at 259. The Ninth Circuit recently addressed the question of whether the goal of CAA encompassed considerations of gasoline availability and cost in a similar context in *Oxygenated Fuels Ass'n, Inc. v. Davis*, 331 F.3d 665 (9th Cir. 2003) ("*Davis*"), an action by the

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[1] In *OFA v. Pataki*, this Court rejected plaintiff's argument, based on *Geier v. American Honda Motor Co.*, 529 U.S. 861 (2000), that oxygenate choice is a goal of CAA. *See* 158 F. Supp.2d at 260, n.6. Subsequent to that decision, the Ninth Circuit rejected a similar argument in *OFA v. Davis*, 331 F.3d 665, 672 (9th Cir. 2003). Plaintiff raises the argument again in its post-trial Memorandum of Law. The Court sees no reason to reconsider its previous conclusion.

same association as the plaintiff herein. In support of their contention that California's ban on MTBE gasoline is conflict-preempted by CAA, OFA argued that California's law would interfere with CAA's goal to "ensure a smoothly functioning market and cheap gasoline[.]" The Ninth Circuit rejected this contention and dismissed the case, stating: "We take it as true that Congress wanted to reduce pollution caused by motor vehicles, but at the same time did not want to harm the nation's economy by causing gasoline prices to rise substantially." 331 F.3d at 673. The Ninth Circuit further stated that it is "questionable" whether a smoothly functioning market is a goal of the Clean Air Act and that "saying that Congress might not have wanted to cause a substantial increase in gasoline prices is not the same as saying that assuring inexpensive gasoline was a goal of the Act." *Id.*

In its most recent Memorandum-Decision and Order, decided October 3, 2003, this Court noted that the above-quoted observations in *Davis*

> do not evince an extremely narrow reading of the goals of the Clean Air Act and thus are not necessarily incompatible with this Court's conclusion that "the congressional goal in enacting the RFG program was to reduce emissions pollution while ensuring an adequate gasoline supply at a reasonable cost, taking into account other health and environmental concerns so far as reasonable." [*OFA v. Pataki*,] 158 F. Supp.2d at 259.
>
> If, on the other hand, *Davis* is read as adopting an extremely narrow reading of the goals of the Clean Air Act, the Court declines to follow it. It cannot reasonably be argued that Congress' goal was to reduce emissions pollution regardless of the cost – even, for the sake of argument, at the cost of total disruption of the gasoline market, complete unavailability of gasoline in certain regions of the nation, or astronomical increases in prices. This Court does not view the goals of the Clean Air Act so narrowly as to exclude from all consideration the "larger context of market forces, health and environmental impacts, regional priorities, technological feasibility and other considerations. *OFA v. Pataki*[], 158 F.Supp.2d at 256.

Thus, in this Court's view, ensuring an adequate supply of gasoline at reasonable cost is not, viewed in isolation, a goal of CAA; rather, CAA's goal of enhancing air quality must be viewed in the larger context of market forces, health and environmental impacts, regional priorities, technological feasibility and other considerations.

Accordingly, at trial, plaintiff adduced evidence for the purpose of showing (1) that the N.Y. MTBE Law would cause increased air pollution, and (2) that N.Y. MTBE Law would interfere with the existence of an adequate gasoline supply at a reasonable cost. Defendants primarily directed their efforts at trial to challenging plaintiff's evidence.[2]

Plaintiff's case, generally

Essentially, plaintiff's contentions at trial were that as a result of N.Y. MTBE Law, refineries will supply RFG containing ethanol, the only viable oxygenate alternative to MTBE; that the use of ethanol RFG will cause increased emissions of volatile organic compounds ("VOC") and oxides of nitrogen ("NOx"), which are ozone precursors; that the resulting increased emissions of ozone precursors will be in the range of 20 tons per day; that these increased emissions will impair New York's ability to comply with CAA; and that the economic impacts of N.Y. MTBE Law bolster the conclusion that the law will interfere with the goals of CAA. In support of these contentions, plaintiff presented three expert witnesses.

Plaintiff built its case on the testimony of David Hirshfeld, an expert in refinery

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[2] The Court rejects plaintiff's contention that the Court should draw an adverse inference against defendants from defendants' decision not to call one of their experts, Gary Whitten, as a witness at trial. *See generally United States v. Caccia*, 122 F.3d 136, 138 (2d Cir. 1997). Plaintiff has the burden of coming forward with proof supporting its claims. Defendants have no affirmative obligation to prove anything and may prevail simply by attacking essential elements of plaintiff's case – in large part, this what defendants did in this trial. It is not clear what inference the Court could properly draw under the circumstances. At most, the Court can infer that Whitten would not have succeeded in refuting any part of plaintiff's proof and that therefore calling him would have accomplished the same thing as not calling him; certainly, the Court could not reasonably infer that Whitten would have supplied a missing element in plaintiff's case.

modeling. Hirshfeld testified that, using linear programming modeling, he compared the projected emissions properties of ethanol RFG with those of MBTE RFG and concluded that "the average emissions properties of ethanol blended gasoline RFG that New York would receive after a ban will be slightly worse than the emissions properties of MTBE."

Plaintiff next introduced the testimony of Thomas Austin, an air pollution control expert, who testified that the use of ethanol instead of MTBE will cause increased emissions of ozone precursors from four sources: evaporative emissions, exhaust emissions, commingling and permeation. He attributes these increases in part to the undisputed fact that the use of ethanol RFG increases the vapor pressure of gasoline.

Plaintiff's final witness on its direct case was Gordon Rausser, an economist. Rausser testified that N.Y. MTBE Law will result in gasoline supply shortfalls and price increases in New York.

Hirshfeld's testimony

Plaintiff's refinery modeling expert, David Hirshfeld, testified that he predicted the emissions properties of ethanol RFG using a linear programming model known as Advanced Refinery Modeling System ("ARMS"), which his company developed. Hirshfeld explained that EPA provides refiners with a model known as the complex model and that refiners may make RFG with any combination of eight properties, provided that, pursuant to the complex model, the RFG meets the exhaust and evaporative emissions standards for VOC, NOx and toxics. He agreed that "an absolute bedrock premise in [his] modeling work is that refiners comply with the law" and that when MTBE RFG is banned, the refinery sector will provide ethanol RFG which complies with the complex model. Therefore, according to Hirshfeld, using the complex model and taking economic and other considerations into account, the ARMS model can predict the amounts of the eight properties the refineries are likely to utilize in providing ethanol RFG to New York.

Hirshfeld further testified, based on the ARMS model, that the reductions in emissions properties achieved by the ethanol RFG which refiners were likely to provide would be inferior to the reductions achieved by MBTE RFG. In other words, ethanol RFG would produce emissions reductions that were "less good" than those produced by MBTE RFG, although there would still be reductions. He stated that the difference in emissions when ethanol RFG replaces MTBE RFG in New York would be "small." He further stated that New York overcomplies with the RFG standards and that with ethanol RFG there would be a decrease in overcompliance, although there would still be overcompliance.[3]

Hirshfeld's emissions projections based on his ARMS model were wholly discredited at trial. The Court bases this conclusion on the testimony of defendants' refinery modeling expert Martin R. Tallett, on defendants' cross-examination of Hirshfeld upon plaintiff's direct case, and, most importantly, on defendants' cross-examination of Hirshfeld upon rebuttal. On cross examination upon rebuttal, Hirshfeld admitted that in running the ARMS model for MTBE RFG he had placed numerical constraints on certain of the eight properties of gasoline, specifically aromatics, olefins and benzene; in other words, he had predetermined or "fixed"

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[3] There was evidence at trial that the decreased emissions reductions in New York might be offset by improved reductions in non-attainment areas in the northeast outside of New York State, primarily in northern New Jersey, which is part of the New York-Northern New Jersey-Long Island severe nonattainment area and is upwind of New York. Having concluded that plaintiff has not made its case, the Court does not deem it necessary to consider this or other evidence which tends to contradict plaintiff's proof.

maximum numbers for these properties. He admitted that under the complex model, aromatics and olefins have significant effects on NOx emissions, and in some cases on VOC as well. He did not claim that he imposed any constraints on aromatics or olefins in running the model for ethanol RFG. Hirshfeld gave no credible explanation for the presence of these constraints, referring only in a conclusory manner to unspecified "customary refining practice" and stating that he imposed the constraints as an aspect of his "professional judgment."

Defendants' expert Tallett testified that when he ran the same cases after removing the constraints on aromatics, olefins and benzene, he found that Hirshfeld's ARMS model predicted in some cases that switching to ethanol RFG would reduce VOC and NOx emissions by as much as two percent. Tallett further testified that fixing these properties was inconsistent with the function and purpose of the complex model, which is designed to allow refiners flexibility to vary gasoline properties. Tallett further testified that the constraints were improper because the purported aim of Hirshfeld's study was to predict the amount of each gasoline property the refiners would use in exercising that flexibility. Further, by limiting aromatics and olefins only for MTBE RFG and not for ethanol RFG, Hirshfeld placed a ceiling on MTBE's emissions while allowing the ethanol emissions to rise with no limitation.[4]

Hirshfeld did not voluntarily disclose that he had placed constraints on the aromatics, olefins and benzene for MTBE RFG, nor did he ever give a credible explanation for having done so. In his testimony throughout the trial he attempted to convey the impression that he

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[4] The Court rejects Hirshfeld's effort to discredit Tallett's results. Hirshfeld merely stated that he was told by his partner Kolb that Kolb was unable to replicate Tallett's results. As a result of Hirshfeld's apparent lack of knowledge about how Kolb reached this conclusion, Hirshfeld's testimony in this regard lacked probative value and deprived defendants of meaningful cross-examination on the issue.

had applied the model in an objective manner and that the results, which were favorable to his client, represented a meaningful comparison of the likely emissions properties of MTBE RFG and ethanol RFG. In fact, the effect of the constraints was to produce results which had the appearance of veracity and reliability but which actually proved nothing. Hirshfeld presented these results with the intention that the Court would rely on them in reaching a decision. For this reason, the Court rejects his testimony in its entirety based on its lack of reliability and credibility.

Although it is not necessary to do so in view of the above finding, the Court observes also that Hirshfeld's credibility and reliability were further damaged by his admission on cross-examination that he had omitted to disclose model results that were unfavorable to plaintiff; he stated that he ran his model thousands of times but only reported about 40 of these runs. He did not satisfactorily explain why he rejected thousands of results or why he selected the particular ones which he reported.

Moreover, Hirshfeld initially ran his model assuming that refiners would choose to use "individual pool" compliance, one of two methods of demonstrating RFG compliance, but he did not disclose the results of these individual pool cases. Tallett demonstrated that these individual pool results were less favorable to plaintiff's case than were the "split pool" cases Hirshfeld reported in his expert reports. Hirshfeld gave no reasonable explanation for reporting the split pool results but not the individual pool results. Tallett also challenged the reliability of Hirshfeld's methodology and conclusions on a number of other grounds. Neither Hirshfeld's rebuttal testimony nor any other part of plaintiff's evidence adequately met those challenges.

The Court further finds that Hirshfeld's own testimony establishes that Hirshfeld resisted providing important aspects of his complex model to defendants' refinery modeling experts, Gary Whitten and Tallett. Hirshfeld failed to provide the ARMS action menu, the calibration cases he used, and a VMP.zip file with export capability. This resistence continued even after a protective order was in place. The Court finds that Hirshfeld's explanations for this conduct are neither reasonable nor credible.

In sum, the Court rejects Hirshfeld's evidence in its entirety based on its lack of reliability and credibility. One final observation regarding Hirshfeld's testimony: even if the Court were to accept Hirshfeld's evidence, his ultimate conclusion was that the average emissions properties of ethanol RFG in New York "will be <u>slightly worse</u> than the emissions properties of MTBE" (emphasis added). In the Court's view, this is not evidence of a conflict of sufficient magnitude to support conflict preemption of New York's law.

Austin's testimony

Thomas Austin, plaintiff's air pollution control expert, testified that the use of ethanol instead of MTBE would cause increased VOC and NOx emissions from four sources, due in part to the undisputed fact that the use of ethanol, the only viable oxygenate alternative to MTBE, increases the vapor pressure of gasoline. First, the increased vapor pressure would increase emissions through evaporation. Second, ethanol RFG use would cause increased exhaust emissions. Third, adding ethanol to gasoline would accelerate the rate of permeation through plastic fuel tanks and rubber hose materials, causing increased emissions. Finally, commingling, which would result from the mixing of ethanol RFG and MTBE RFG, would cause the vapor pressure of the gasoline to rise, resulting in additional emissions.

Austin's testimony that N.Y. MTBE Law would result in increased exhaust and evaporative emissions was based on Hirshfeld's discredited predictions of the emissions properties of ethanol RFG and as such has no probative value. The Court notes also that, based on Hirshfeld's projections, Austin testified that with ethanol RFG, New York would continue to overcomply with the complex model requirements, although to a lesser degree than with MTBE RFG. Thus, even if the Court were to accept Hirshfeld's projections and Austin's testimony based thereon, Austin's predictions of exhaust and evaporative emissions would not aid plaintiff in proving its case.

Austin's initial commingling projections were shown to be based on incorrect figures, and he did not present corrected projections. His testimony regarding permeation, although not based on Hirshfeld's testimony, depended heavily on a five-year-old survey of 324 California residents; for this and other reasons it has negligible probative value. In his rebuttal testimony,[5] Austin introduced revised and significantly higher predictions of permeation emissions. He essentially abandoned his former reliance on Hirshfeld's calculations by downplaying his exhaust and evaporative emissions projections, which were based on Hirshfeld's calculations, and emphasizing his newly revised permeation projections, which were not based on Hirshfeld's calculations.

Aside from the credibility issues inherent in the timing of these last-minute upward

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[5] Defendants objected that this was not proper rebuttal testimony and moved to preclude or strike this evidence. The Court reserved decision on the motion and permitted plaintiff to introduce Austin's rebuttal testimony. In view of the importance of the issues and the need for a complete record, the time pressures under which the parties and the Court were operating, the latitude which the Court afforded both sides in preparing and presenting their cases, and the fact that at the close of Austin's rebuttal testimony defendants did not seek an opportunity to introduce further evidence to refute it, the Court denies the defendants' motion.

revisions, Austin's testimony falls short of supporting plaintiff's claims in a fundamental respect: although he projected an increase in emissions of VOC and NOx in an amount of 20 tons per day, he did not predict the amount of ozone which would result from this increase. Austin admitted that calculating an amount of ozone resulting from amounts of ozone precursors is "not as simple as just a one-to-one linear relationship between precursors and results in ozone" and that translating a change in the amount of ozone precursors into a change in the amount of ozone "is a fairly complex process that involves the use of modeling and having to look at more than just the specific change" in the amounts of precursors. Austin described several methods for performing this "translation" of amounts of ozone precursors into an amount of ozone, including (1) photochemical modeling, which Austin described as the "best" and "most precise" way to calculate the quantity of ozone; (2) a "proportional" analysis, involving looking at the ratio of emissions before and after the change; and (3) the Empirical Kinetic Modeling Approach, which he described as "a simplified way of incorporating the photochemistry that's known to take place without having to go to the complication of running an actual air shed model." Neither Austin nor his staff performed any of these methods; Austin stated that it was beyond the scope of what he was trying to accomplish in his reports. Thus, plaintiff did not present projections of any specific amount of increase in ozone which will result from N.Y. MTBE Law. Nor did it provide a context in which the Court could evaluate the significance of this increase. The "empirical data" from California and the Chicago-Milwaukee area does not assist plaintiff in filling this gap; the record contains no basis to find that the limited conclusory evidence pertaining to those areas is relevant to the New York area.

Due to the above and other shortcomings, Austin's testimony does not establish that N.Y. MTBE Law will increase ozone pollution to an extent which will interfere with the achievement of the goals of CAA.

Carl Johnson's testimony; DEC waiver request

Plaintiff urges the Court to view Austin's prediction of increased emissions in combination with the testimony of defendants' witness Carl Johnson, DEC Deputy Commissioner, that New York has "very little cushion in terms of meeting attainment" with NAAQS and that the additional emissions from the MTBE ban would "interfere" with New York's ability to attain the ozone standard. The Court finds, however, that read in context, Johnson's testimony does not support plaintiff's case. Essentially, Johnson explained that DEC "would have to" address any increase in emissions from the MTBE ban or any other source and that it would do so by exploring every available avenue of emissions reduction, including non-road vehicles, generators, portable gas containers, paint and consumer products. Thus, in effect, Johnson testified that any increased emissions from a source such as the MTBE ban would "interfere with" or "impede" DEC's efforts only to the extent that it would compel DEC to find compensating sources of reductions, but that nevertheless, DEC "would have to" find these compensating sources, and the reductions would ultimately be achieved.

Likewise, to the extent that plaintiff would have the Court rely on DEC's statements in its January 6, 2003 request to EPA for a waiver of the RFG oxygenate requirement, the Court accepts the testimony and explanations given by Johnson and declines to draw contrary conclusions from the waiver request. Neither DEC's waiver request nor any part of Johnson's testimony adds support to plaintiff's case.

Gordon Rausser's testimony

With respect to economic impacts of N.Y. MTBE Law, the Court has stated that ensuring an adequate supply of gasoline at reasonable cost is not, viewed in isolation, a goal of CAA, but that it does not view the goals of CAA so narrowly as to exclude from all consideration the "larger context of market forces, health and environmental impacts, regional priorities, technological feasibility and other considerations." *OFA v. Pataki*, 158 F.Supp.2d at 256. The Court further observed in its October 3, 2003 Memorandum-Decision and Order: "It cannot reasonably be argued that Congress' goal was to reduce emissions pollution regardless of the cost – even, for the sake of argument, at the cost of total disruption of the gasoline market, complete unavailability of gasoline in certain regions of the nation, or astronomical increases in prices." A short-term or relatively small impact on prices and/or supply, however, would not support a finding that N.Y. MTBE Law interferes with the achievement of the goals of CAA.

Plaintiff's economics expert, Gordon Rausser, testified that N.Y. MTBE Law would transform New York into a boutique fuel market and cause New York to experience at least a 10% supply shortfall "in the short run" (that is, up to about six months). He further stated that the law would cause greater price volatility, with price spikes between 25% and 100% in the short run and between 6% and 16% thereafter. He based his predictions of supply shortfalls and price increases on the assumption that suppliers will reduce their supply of RFG to New York by 5 to 10 percent if MTBE is banned; plaintiff does not, however, present an adequate evidentiary basis for this assumption. Much of his testimony is speculative and has insufficient evidentiary support. Plaintiff has not made its case regarding the economic impacts of N.Y. MTBE Law; accordingly, it is not necessary to resolve factual disputes between Rausser's testimony and that of defendants' expert, Robert Reynolds.

In any event, even accepting Rausser's predictions, the Court finds that the predicted effects are not of sufficient magnitude to support a finding of conflict preemption. At most, Rausser has projected a relatively small overall impact, the most severe elements of which would last no more than six months. Plaintiff has not shown that the economic impacts of N.Y. MTBE Law will interfere with the achievement of the goals of any aspect of CAA.

FINDINGS OF FACT

For the reasons set forth above, the Court finds that plaintiff's refinery modeling expert, David Hirshfeld, is not a reliable or credible witness and that therefore his testimony and his conclusion that the reductions in emissions achieved by ethanol RFG would be inferior to the reductions achieved by MBTE RFG are entirely discredited. Hirshfeld's testimony, therefore, does not aid plaintiff in proving its case. Further, even if the Court were to accept Hirshfeld's testimony, his ultimate conclusion was only that the average emissions properties of ethanol RFG in New York "will be <u>slightly worse</u> than the emissions properties of MTBE" (emphasis added); the Court finds that this does not constitute evidence that N.Y. MTBE Law would cause an increase in emissions of significant magnitude to support plaintiff's case.

For the reasons set forth above, the Court further finds that the testimony of Thomas Austin, plaintiff's air pollution control expert, does not support plaintiff's claim that N.Y. MTBE Law would result in increased exhaust and evaporative emissions. This testimony was based on Hirshfeld's discredited predictions of the emissions properties of ethanol RFG and because Austin testified that with ethanol RFG, New York would continue to overcomply with the complex model requirements, although overcompliance would be reduced in an unspecified amount. With respect to permeation, the Court finds that Austin's testimony has negligible probative value because it depended heavily on a five-year-old survey of 324 California residents and because its credibility was significantly undermined by the timing of his upward revisions on rebuttal. Moreover, Austin's testimony does not support plaintiff's claims because, although he projected an increase in emissions of VOC and NOx in an amount of 20 tons per day, he did not predict the amount of ozone which would result from this increase, thus providing no evidence of the significance of this increase. Nor did he provide a context in which the Court could evaluate the significance of this increase. As stated above, the Court further finds that the "empirical data" from California and the Chicago-Milwaukee area does not assist plaintiff. Thus, the Court finds that Austin's testimony does not constitute evidence that N.Y. MTBE Law will increase ozone pollution in any significant amount.

For the reasons discussed above, the Court further finds that neither Carl Johnson's testimony nor DEC's January 6, 2003 request to EPA for a waiver of the RFG oxygenate requirement adds support to plaintiff's case.

With respect to economic impacts of N.Y. MTBE Law, the Court finds that the testimony of plaintiff's economist, Gordon Rausser, was speculative and has insufficient evidentiary support and that therefore plaintiff has not made its case regarding the economic impacts of N.Y. MTBE Law. Moreover, even accepting Rausser's predictions, the Court finds that the predicted effects are not of sufficient magnitude to support a finding that the economic impacts of N.Y. MTBE Law will interfere with the achievement of the goals of CAA.

CONCLUSIONS OF LAW

Plaintiff has based its challenge to N.Y. MTBE Law on the contention that the law will stand as an obstacle to the accomplishment and execution of the full purposes and objectives of Congress in various aspects of CAA. First, the Court concludes that plaintiff has not shown that N.Y. MTBE Law will interfere with the goal of the CAA's RFG program to reduce emissions of VOC, NOx and toxics through the reformulation of conventional gasoline. This goal will be advanced by the use of any approved RFG. Moreover, both Hirshfeld and Austin testified that with ethanol RFG, New York would still overcomply with the RFG emissions standards, albeit to a lesser extent than with MTBE RFG. Thus, when N.Y. MTBE Law goes into effect, New York will continue to advance the goal of the RFG program by using ethanol RFG.[6]

Nor has plaintiff shown that N.Y. MTBE Law will interfere with accomplishment of the goals of CAA generally. As noted, Hirshfeld's evidence was entirely discredited; in any event, his ultimate conclusion that N.Y. MTBE Law would cause a "slight" deterioration in RFG emissions properties does not support plaintiff's case. As discussed above, Austin's evidence that N.Y. MTBE Law will cause decreased reductions in ozone precursors does not demonstrate that N.Y. MTBE Law will affect ozone to an extent that would interfere with the goals of CAA. Rausser's evidence was speculative and lacking in sufficient evidentiary support. In any event, Rausser did not project economic impacts from N.Y. MTBE Law of sufficient magnitude to support the conclusion that the law would impede accomplishment of

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[6] Both Hirshfeld and Johnson testified that if MTBE gasoline is banned in New York, the refinery sector will provide to New York ethanol gasoline which complies with the RFG program.

the goals of CAA.

Plaintiff further urges that N.Y. MTBE Law will frustrate achievement of the goals of CAA because it will cause New York's ozone levels to exceed the ozone NAAQS in 2007. The Court is not persuaded that NAAQS constitutes an expression of the goals of CAA such that a state's failure to achieve NAAQS would necessarily impair achievement of the goals of CAA. Moreover, it is doubtful whether any prediction that a state will fail to achieve NAAQS in 2007 could support a finding of conflict preemption in 2003. In any event, plaintiff has not demonstrated that New York will fail to achieve the ozone NAAQS in 2007. As noted, although Austin predicted a 20-ton per day increase in emissions of ozone precursors, he did not predict any specified amount of ozone increase resulting from the MTBE ban, nor did he provide a context in which the Court could evaluate the significance of this increase. Nor does Johnson's testimony nor any other part of the record establish that N.Y. MTBE Law will prevent New York from meeting the ozone NAAQS in 2007.

Likewise, the Court also rejects any contention that N.Y. MTBE Law is conflict-preempted on the ground that it will prevent the state from complying with the State Implementation Plan ("SIP"). Johnson characterized SIP as "the collection[] of actions that the state of New York is going to take in order to meet attainment in 2007." There is no evidence that New York's SIP requires the use of MTBE RFG or prohibits the use of ethanol RFG. As with NAAQS, the Court is not persuaded that SIP constitutes an expression of the goals of CAA, nor does the evidence show that N.Y. MTBE Law will prevent New York from achieving SIP.

In enacting N.Y. MTBE Law to protect its citizens from groundwater contamination, the State of New York exercised a power traditionally reserved to the States. *See Hillsborough*, 471 U.S. at 715. In urging the Court to strike down this enactment on the ground that it conflicts with federal law, plaintiff must overcome the presumption in favor of the constitutionality of the state law. *See id.* at 716. This it has not done. For the reasons set forth above, the Court concludes that plaintiff has not demonstrated that N.Y. MTBE Law stands as an obstacle to the accomplishment and execution of the full purposes and objectives of Congress in enacting CAA. The Court reaches this conclusion regardless of whether CAA's goal of enhancing air quality is viewed as limited to air quality alone, or whether it is viewed in the larger context of market forces, health and environmental impacts, regional priorities, technological feasibility and other considerations. *See OFA v. Pataki*, 158 F.Supp.2d at 256.

It is therefore

ORDERED that judgment shall be entered dismissing the complaint in its entirety on the merits.

IT IS SO ORDERED.

November 21, 2003
Syracuse, New York

Hon. Norman A. Mordue
United States District Judge

PROGRAM REPORT :

EMISSION IMPACTS OF FUELS TO ACCOMMODATE THE NEW YORK STATE OXY-WAIVER REQUEST AND MTBE BAN

New York State Department of Environmental Conservation
Division of Air Resources : Bureau of Mobile Sources
Automotive Emissions Laboratory

May 6, 2003

EXECUTIVE SUMMARY

In view of an upcoming ban on the use of methyl tertiary butyl ether (MTBE) in gasoline in New York State and extensive debate in Congress over the introduction of renewable fuels and the future of the oxygenate requirement in reformulated gasoline (RFG), the New York State Department of Environmental Conservation (DEC) conducted a study of tailpipe emissions from in-use vehicles. This study suggests that oxygenates added to gasoline produce no air quality benefits; thus, there is no need to continue requiring oxygenate in gasoline.

New York State law bans the use of MTBE in gasoline beginning January 1, 2004, due to concerns of the impacts of MTBE in gasoline spills. MTBE has been used in the New York City Metropolitan Area (NYCMA) to satisfy the requirement of the 1990 Clean Air Act Amendments that severe non-attainment areas must use reformulated gasoline that is at least 2 percent oxygen by weight. However, that oxygenate requirement predates the large-scale introduction of motor vehicles with modern computerized engine control systems. Staff of the DEC Automotive Emissions Laboratory (AEL) hypothesized that the fuel management systems in vehicles in current use would adjust engine function to compensate for the additional oxygen in the fuel, thus negating any previous benefit from the oxygenate.

This study looked at previous studies conducted by other researchers, and a test program conducted at AEL. The emissions date from these studies led DEC to conclude that no significant tailpipe emissions increases could be attributed to fuel changes when MTBE was replaced by ethanol, or when no oxygenate was present in the fuel. AEL also looked at on-board diagnostics (OBD II) data generated during the test program, and concluded that modern computer controls adapt to the residual oxygen content in the exhaust, and adjust fuel delivery to maintain proper catalyst function. The research supports the hypothesis that adding an oxygenate is unnecessary.

DEC has already requested that the United States Environmental Protection Agency (EPA) waive the RFG oxygenate requirement for NYCMA. This study will be submitted as part of the ongoing review of that waiver request. If approved, NYCMA equivalent RFG could be produced without any oxygenate additive. Without this waiver, ethanol will likely be used as an oxygenate, as it is in other RFG areas in the country. In some of these areas EPA has granted a relaxation of the VOC evaporative standards for ethanol blends. DEC estimates a 4.4 ton per day increase in mobile source VOC evaporative emissions if this occurs in New York.

SCOPE

This paper is limited to a discussion of the vehicle emissions aspects of an MTBE[1] ban in New York State. The distribution of fuels and oxygenates, economic impacts, water quality concerns and other critical issues important to a full assessment of the New York MTBE ban are not discussed here.

INTRODUCTION

New York State legislation has made the use of MTBE in gasoline illegal after January 1, 2004, due to concerns regarding water quality. The 1990 Clean Air Act Amendments require the New York City metropolitan area (NYCMA) to use a reformulated gasoline (RFG) that is at least 2% by weight (wt.%) oxygen. Currently, almost all RFG sold in the NYCMA contains MTBE as an oxygenate. The pending New York MTBE ban would require a substitute oxygenate to satisfy the federal oxygenate requirement, and to replace octane contributed by MTBE. At present, only ethanol can be produced in sufficient quantity to serve as an oxygenate substitute for MTBE in NYCMA RFG. Ethanol, however, also poses risks to air and water quality that had previously prompted the New York State Department of Environmental Conservation (DEC) to seek alternatives to ethanol use in gasoline.

To avoid the environmental risks posed by ethanol as an MTBE substitute, DEC has requested that EPA waive the NYCMA RFG 2 wt.% oxygen requirement. If EPA approves the waiver request, NYCMA "equivalent" RFG (ERFG)[2] could be produced without an oxygenate additive (or, at least, with less added oxygenate) so long as the non-oxygenated ERFG meets all other RFG performance standards. EPA, however, denied a similar oxygenate waiver request by California.

As part of the DEC effort to assess the air quality impact of an MTBE ban, vehicular exhaust emission testing with MTBE RFG, ethanol RFG, and a non-oxygenated ERFG was conducted at the DEC Automotive Emissions Laboratory (AEL).

INDUSTRY FUEL STUDIES

Auto/Oil Study and the Complex Model

Much of the research on oxygenated gasoline emissions effects occurred during the development and implementation of federal RFG rules in the 1990 Clean Air Act Amendments. During the early 1990s, the automotive and oil industries conducted a multimillion dollar research effort known as the Auto/Oil Air Quality Improvement Research Program (Auto/Oil). At about the same time, EPA also conducted a series of large scale research projects.

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[1] See Table of Acronyms at end of text.

[2] The term "RFG" has become synonymous with "federal RFG", which is an RFG formulation with a minimum 2 wt.% oxygen as prescribed by the 1990 Clean Air Act Amendments for ozone nonattainment areas. Consequently, "non-oxygenated RFG" may be inappropriate terminology and we therefore introduce the term "equivalent" RFG (ERFG) to describe the non-oxygenated fuel used in this study.

Studies regarding the choice of oxygenate and the effect and oxygen content on emissions were but small portions of these research projects, yet generated most of the data for development of the EPA Complex Model that is used to demonstrate fuel compliance with RFG rules. Consistent with Clean Air Act requirements, these studies were limited primarily to 1990 and earlier technology vehicles.

Alliance of Automobile Manufacturers Study

One of the few recent oxygenated fuel studies was conducted by the Alliance of Automobile Manufacturers (AAM) in response to California regulatory initiatives, including the California MTBE ban. The AAM research encompassed both oxygenates and fuel sulfur content. The AAM study attempts to identify the effects of the chemicals (MTBE and ethanol). This is common for fuel effects studies. Although more cars were tested by AAM, only 5 were tested on all 3 fuels.

AAM research employed three test gasolines: (1) a non-oxygenated gasoline used as a base fuel; (2) a 2 wt.% oxygen MTBE gasoline produced by blending 11% by volume MTBE to the base non-oxygenated fuel; (3) a 4 wt.% gasoline produced by blending 11% by volume ethanol to the base non-oxygenated fuel. Except for the added oxygenate, the gasoline composition was identical for each test fuel, thus differences in emissions among the test fuels should have been due to differences in the oxygenates and resultant oxygen content.

Because AAM was attempting to identify chemical specific emissions effects, none of the test gasolines in this study would have met the Complex Model VOC and toxics reduction properties of RFG currently sold in the NYCMA. DEC reanalyzed this data to treat each vehicle as an individual, similar to the treatment of the vehicles in the DEC study described below.

DEC analysis of these 5 cars data shows both oxygenated AAM fuels reduced CO emissions compared to the base AAM fuel. Neither MTBE nor ethanol as an oxygenate was consistently superior to the other. Comparison of engine out emissions (before the catalytic converter) to tailpipe emissions suggested that catalytic converter CO removal efficiency increased with oxygenated fuels relative to the base fuel.

DEC AEL TEST PROGRAM

Overview of the DEC AEL Test Study

To evaluate potential vehicular emission impacts associated with an MTBE ban, AEL conducted an emission testing study in late 2002. The study employed two high mileage (120,000 and 155,000 miles) DEC light-duty fleet vehicles: a 1998 Plymouth Breeze and a 1997 Oldsmobile Achieva. Three RFG test fuels were formulated for and used in this study : an MTBE RFG; an ethanol RFG; and a non-oxygenated ERFG. Federal certification fuel (cert fuel) was also used in this study as a reference fuel, with cert fuel testing preceding the first RFG fuel test and following the last RFG fuel test for each vehicle. On each day of testing, six emissions tests, using six different emission test cycles, were performed on one test vehicle. A total of 245 valid emission tests were conducted over the course of this study. One cycle was rejected due to a miss-start at the beginning of FTP Bag 1 on the Plymouth Breeze.

Inasmuch as the three study RFGs were specified to meet the same EPA Complex Model RFG emission targets, extreme differences in exhaust emissions among the study RFGs would not be expected, and differences may not be due to the different oxygenate or lack of oxygen in the fuel.

Both test vehicles were tested on certification fuel at the start and end of each vehicle testing period. Significant variations in initial and final cert fuel emissions were often observed, thus complicating assessment of fuel composition effects on emissions. Appendix B provides a qualitative and quantitative summary of specific fuel comparison emission difference observations. DEC cautions that the emissions data from these two vehicles can not **and** should not be extrapolated to an entire fleet.

Engine Control System Monitoring

A key aspect of the AEL study was the evaluation of engine control system response to changes in fuel properties. To this end, realtime OBD-II data were collected, analyzed, and evaluated. Appendix C presents typical results for both vehicles.

Study OBD-II data indicate that engine control systems in both vehicles always attempted to maintain closed-loop operation, with the air/fuel ratio (AFR) constantly oscillating slightly above and below the stoichiometric AFR (dithering) to optimize and maintain catalyst function. Differences in test fuel oxygen content effected changes in engine control system signals, especially the long term fuel trim and AFR dithering.

Analysis of the OBD II data showed that both vehicles control systems operated to maintain proper 3-way catalyst operation regardless of fuel oxygen content. The control systems achieve residual oxygen levels that are independent of the oxygen content of the fuel. See Appendix C for an expanded discussion of the OBD II data analysis.

NON-EXHAUST EMISSIONS[3]

Complex Model Treatment of the Non-Exhaust Emissions

The Complex Model is used to determine fuel compliance with RFG regulations re tailpipe emissions, but also contains a non-exhaust component that models evaporative emissions, running losses, and refueling losses. The Complex Model, however, does not model resting losses, fuel leakage, permeation, and commingling effects. Nor does the Complex Model provide projections for Tier 1, Tier 2, California LEV, or NLEV vehicles or consider on-board vapor recovery systems. Enhanced I/M with purge and pressure checks and gasoline station Stage 2 pump controls, however, are all assumed to be in use in Complex Model projections. Complex Model non-exhaust VOC is influenced only by fuel RVP; consequently, the fuel oxygenate does not directly influence Complex Model projections of evaporative emissions.

The Auto/Oil study and other studies have found that the addition of ethanol to non-oxygenated gasoline increases RVP. Ethanol concentrations typical of RFG increase RVP about 1 psi relative to the base non-oxygenated gasoline. Decreasing the RVP of the base non-oxygenated gasoline can compensate for the RVP increase due to addition of ethanol.
So long as Complex Model generated regulatory emission targets remain constant, RVP driven non-

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[3] AEL is not equipped to perform evaporative emissions testing.

exhaust emission increases are unlikely. However, EPA has relaxed the Complex Model performance targets for 10% ethanol blended RFG in the Chicago/Milwaukee RFG area. If a similar concession were to be made in the NYCMA, a 4.4 ton/day (1% to 2%) increase in mobile source related hydrocarbon emissions is predicted by DEC.

Two additional sources of potential increases in non-exhaust emissions must be addressed: commingling and permeation. Commingling is the mixing of an ethanol blended gasoline with a non-ethanol blended gasoline. As noted above, adding ethanol to gasoline, even in small quantities, increases evaporative emissions. If consumers purchase both ethanol and non-ethanol gasolines, the resultant blending in vehicle fuel tanks would increase evaporative emissions relative to both the ethanol gasoline and the non-ethanol gasoline.

Commingling is most likely if some RFGs contain ethanol and other RFGs do not. If all RFG contains ethanol, commingling will be limited to cases where vehicle owners purchase fuel from conventional, non-RFG, gasoline stations. The magnitude of commingling induced evaporative emission increases cannot be predicted.

Permeation is the physical movement of hydrocarbon molecules through plastic and rubber fuel system components. Permeation ultimately leads to evaporation of hydrocarbons into the ambient atmosphere. The limited published research on permeation suggests that ethanol may increase permeation emissions by a factor of six, which, if true, would translate to 6.1 tons/day of additional evaporative hydrocarbon emissions in the NYCMA ozone nonattainment area as a result of conversion to ethanol RFG in the area.

These concerns were significant factors that led DEC to request an EPA waiver of the NYCMA RFG oxygen content requirement.

SUMMATION

Within the limitations and caveats cited herein, this study suggests the following:

- Fuel oxygenates are not necessary to achieve the benefits of RFG.
- MTBE and ethanol blended RFGs have very similar exhaust emissions.
- Current technology vehicles use technologically advanced sensors and computers to effectively compensate for most fuel property differences.
- Literature data indicate that ethanol increases non-exhaust emissions by increasing the volatility (RVP) of gasoline, by increasing permeation losses, and through commingling effects.

TABLE OF ACRONYMS

MTBE	methyl tertiary butyl ether
NYCMA	New York City metropolitan area
RFG	reformulated gasoline
DEC	Department of Environmental Conservation
ERFG	equivalent RFG
AEL	Automotive Emissions Laboratory
Auto/Oil	Auto/Oil Air Quality Improvement Research Program
AAM	Alliance of Automobile Manufacturers
VOC	volatile organic compounds
Cert	certification fuel or gasoline
Chevron Phillips	Chevron Phillips Chemical Company
ppm	parts per million
OBD-II	on-board diagnostics second generation
FTP	Federal Test Procedure
HFET	Highway Fuel Economy Test
NYCC	New York City Cycle
SFTP	Supplemental Federal Test Procedure or USO6
AFR	air/fuel ratio
LEV	low emission vehicle
NLEV	national low emission vehicle
RVP	Reid vapor pressure
gpm	grams per mile
CVS	constant volume sampler
RT	realtime
CL	confidence Level
UCL	upper confidence limit
LCL	lower confidence limit

APPENDIX A

CERTIFICATES OF ANALYSES FOR FOUR TEST FUELS

The following pages are Certificates of Analyses for the four test fuels used in this program. These certificates were prepared by Chevron Phillips Chemical Company.

Pg.	Chevron Phillips nomenclature	DEC nomenclature
A9	Baseline fuel, UTG 91	Certification Fuel
A10	Oxygenated Test Gasoline (ethanol)	Ethanol RFG
A11	Oxygenated Test Gasoline (NY-MTBE)	MTBE RFG
A12	Octane Test Fuel (NON-OXY)	Non-Oxygenated ERFG

DATE OF SHIPMENT
09-19-02

CUSTOMER PO NO.
A200206

SALES ORDER NO.
5602619

4 X 54 GALLON DRUM

MFG. DATE: 06-2002

CERTIFICATE OF ANALYSIS
BASELINE FUEL
UTG 91
LOT 2FPU9101

Tests	Results	Specifications	Method
Specific Gravity, 60/60	0.7399	0.7343 - 0.744	ASTM D-4052
API Gravity	59.74	Report	ASTM D-1298
Phosphorous, g/gl	<0.001	0.002 Max	ASTM D-3231
Sulfur, ppm	34.4	1000 Max	ASTM D-2622
Silicon, ppm	<0.1	4.0 Max	ICP/AES or X-ray
Manganese, mg/l	<0.1	2.0 Max	ASTM D-3831
Copper Corrosion 3 hrs @ 50°C	1A	1 Max	ASTM D-130
Hydrogen, wt%	13.8	Report	Phillips
Carbon, wt%	86.2	Report	Phillips
Net Heat of Combustion, btu/lb	18559	Report	ASTM D-240
MTBE, lv%	0	0 Max	ASTM D-4815
ETBE, lv%	0	0 Max	ASTM D-4815
Methanol, lv%	0	0 Max	ASTM D-4815
Ethanol, lv%.	0	0 Max	ASTM D-4815
Existent Gums (mg/100ml)	3.4	Report	ASTM D-381
Existent Gums (mg/100ml)(washed)	2.2	5 Max	ASTM D-381
Reid Vapor Pressure	9.17	8.8 – 9.2	ASTM D-323
TEL (ml/gal)	0.000	0.005 Max	ASTM D-3237
Distillation, °F			**ASTM D-86**
IBP	96.8	75 - 95	
5%	120.6		
10	133.0	120 - 135	
20	156.2		
30	177.9		
40	197.5		
50	215.3	200 – 230	
60	231.1		
70	246.1		
80	281.2		
90	322.0	300 – 325	
95	352.5		
EP	399.4	415 Max	
Loss	0.6		
Residue	1.1		
Hydrocarbon Type, Vol%			**ASTM D-1319**
Aromatics	23.6	35 Max	
Olefins	3.4	10 Max	
Saturates	73.0	Report	
Research Octane Number	91.1	90 - 92	ASTM D-2699
Motor Octane Number	83.7	82.5 Min	ASTM D-2700
Antiknock Index	87.4	Report	
Sensitivity	7.4	7.5 Min	

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D. G. Doerr

DATE OF SHIPMENT
09-23-02

CUSTOMER PO NO.
A200206

SALES ORDER NO.
5603580

2 X 54 GALLON DRUM

MFG DATE: 09-2002

CERTIFICATE OF ANALYSIS

OXYGENATED TEST GASOLINE
(ETHANOL)
LOT 2IPOTG03

TESTS	RESULTS	SPECIFICATIONS	METHOD
Specific Gravity, 60/60	0.7290	Report	ASTM D-4052
API Gravity	62.60	Report	ASTM D-1298
Sulfur, ppm	16	30 Max	ASTM D-2622
Corrosion, 3hrs, 50°C	1A	Report	ASTM D-130
Oxygen Content, wt%	1.7	Report	ASTM D-240
Ethanol, lv%	4.4	Report	ASTM D-4815
Existent Gums (mg/100ml)	0	Report	ASTM D-381
Existent Gums (mg/100ml)(washed)	0	Report	ASTM D-381
Reid Vapor Pressure (psi)	6.7	6.6 – 6.8	ASTM D-323
TEL (ml/gal)	0.002	0.005 Max	ASTM D-3237
Benzene Content, lv%	0.32	Report	
DISTILLATION, D-86 °F			**ASTM D-86**
IBP	116.4	Report	
5%	132.1		
10%	138.9		
20%	151.2		
30%	183.2		
40%	203.2		
50%	214.9		
60%	225.9		
70%	241.0		
80%	270.3		
90%	324.5		
95%	360.0		
EP	405.5		
Loss	0.7		
Residue	1.0		
Hydrocarbon Type, Vol%			**ASTM D-1319**
Aromatics	14.7	Report	
Olefins	7.0		
Saturates	78.3		
Research Octane No.	90.5	Report	ASTM D-2699
Motor Octane No.	83.8	Report	ASTM D-2700
Antiknock Index	87.1	87 - 88	

D. G. Doerr teh
D. G. Doerr
Fuels Unit Team Leader

KNC: teh

Chevron Phillips
Chemical Company LP

DATE OF SHIPMENT
09-19-02

CUSTOMER PO NO.
A200206

SALES ORDER NO.
5602619

2 X 54 GALLON DRUM

MFG DATE: 09-2002

CERTIFICATE OF ANALYSIS

OXYGENATED TEST GASOLINE
(NY – MTBE)
LOT 29POTG02

TESTS	RESULTS	SPECIFICATIONS	METHOD
Specific Gravity, 60/60	0.7382	Report	ASTM D-4052
API Gravity	60.2	Report	ASTM D-1298
Sulfur, ppm	15.0	30 Max	ASTM D-2622
Oxygen Content, wt%	1.98	Report	ASTM D-240
MTBE, lv%	11.2	10 - 12	ASTM D-4815
Existent Gums (mg/100ml)(washed)	0	3.0 Max	ASTM D-381
Reid Vapor Pressure (psi)	6.86	6.75 – 6.9	ASTM D-323
TEL (ml/gal)	<0.0006	0.005 Max	ASTM D-3237
Benzene Content, lv%	0.88	Report	
DISTILLATION, D-86 °F			**ASTM D-86**
IBP	106.2		
5%	134.5		
10%	145.0		
20%	160.8		
30%	175.2		
40%	189.6		
50%	203.2	E200 47.7	
60%	224.2		
70%	243.0		
80%	277.9		
90%	330.1	E300 84.2	
95%	365.6		
EP	418.1		
Loss	0.6		
Residue	0.8		
Hydrocarbon Type, Vol%			**ASTM D-1319**
Aromatics	19.9	11.7 – 20.2	
Olefins	13.2	11.1 – 14.1	
Saturates	66.9		
Research Octane No.	91.3	Report	ASTM D-2699
Motor Octane No.	83.1	Report	ASTM D-2700
Antiknock Index	87.2	87 - 88	

D. G. Doerr teh

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Fuels Unit Team Leader

KNC: teh
09/19/02

Chevron Phillips Chemical Company LP

DATE OF SHIPMENT
09-23-02

CUSTOMER PO NO.
A200208

SALES ORDER NO.
5603580

2 X 54 GALLON DRUM

MFG DATE: 09-2002

CERTIFICATE OF ANALYSIS

OCTANE TEST FUEL
NON-OXY
LOT 2IPOTF02

TESTS	RESULTS	SPECIFICATIONS	METHOD
Specific Gravity, 60/60	0.7179	Report	ASTM D-4052
API Gravity	65.60	Report	ASTM D-1298
Sulfur, ppm	15	30 Max	ASTM D-2622
Corrosion 3hrs @ 50°C	1A	1A Max	ASTM D-130
MTBE, lv%	0	0 Max	ASTM D-4815
Ethanol, lv%	0	0 Max	ASTM D-4815
Existent Gums (mg/100ml)	1.9	Report	ASTM D-381
Existent Gums (mg/100ml)(washed)	0.8	Report	ASTM D-381
Reid Vapor Pressure	6.67	6.6 – 6.8	ASTM D-323
TEL (g/gal)	<0.005	0.005 Max	ASTM D-3237
Benzene Content, lv%	0.30	Report	
Distillation °F			**ASTM D-86**
IBP	109.6	Report	
5%	136.1		
10%	149.1		
20%	170.5		
30%	188.9		
40%	203.0		
50%	213.8		
60%	222.8		
70%	236.2		
80%	260.0		
90%	317.1		
95%	354.3		
EP	404.8		
Loss	0.9		
Residue	1.0		
Hydrocarbon Type, Vol%			**ASTM D-1319**
Aromatics	11.5	Report	
Olefins	6.6		
Saturates	81.9		
Research Octane Number	90.0	Report	ASTM D-2699
Motor Octane Number	84.8	Report	ASTM D-2700
Antiknock Index	87.4	87 - 88	

D.G. Doerr / teh

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Fuels Unit Team Leader

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09/23/02

APPENDIX B

We must caution against extrapolation of emissions data in this small study to any real-world vehicle fleet and to real-world driving conditions as the vehicles employed may not be representative of any real-world fleet and the individual driving cycles and laboratory conditions in this study may not be representative of either all possible or integrated real-world driving conditions.

We caution furthermore that data in this study were likely impacted by serious confounding factors and study limitations, most specifically: (1) measured changes in vehicle certification fuel emissions at the end vs the start of the testing period for each vehicle; and (2) test-to-test emissions variability for the same vehicle/cycle/fuel combination about the same as to several times greater than the fuel effect emissions changes predicted by the EPA Complex Model for RFG; (3) extremely small sample sizes for specific vehicle/cycle/fuel comparisons.

The database for this two vehicle fuel comparison study consists of 245 emission tests. In most cases, four replicate tests for each vehicle/cycle/fuel combination were conducted. For one vehicle/fuel combination (Achieva/ethanol-oxygenate gasoline), five replicate tests were performed on each of the 6 test cycles. Data quality assurance investigation resulted in the elimination of some measurements due to possible instrumentation malfunctions or procedure errors; consequently, the database contains only one to three valid emission results for some species in some vehicle/cycle/fuel combinations.

Independent grams per mile (gpm) emission measurements for HC, CO, NO_x, and CO_2 were made using both the Federal Test Procedure (FTP) bag sample method and realtime instrumentation (second-by-second average mass emissions) on the same CVS dilute exhaust. Bag sample ("bag") gpm to realtime (RT) gpm ratios were calculated and investigated, resulting in the discovery of instrumentation or procedure problems and the elimination of some data.

Separate statistical analyses of bag and RT gpm data for specific vehicle/cycle/fuel comparisons were employed to assess possible fuel effect emission differences. Two statistical tests were employed to indicate fuel effects : (1) a t-test comparison of mean values, using a 95%CL and assuming (conservatively) unequal sample variances; and (2) a 95%CL ratio test in which $n \times m$ fuel.1/fuel.2 gpm ratios were computed from the n fuel.1and and m fuel.2 gpm values and in which the binomial probability for the observed number of fuel.1/fuel.2 ratios greater than and less than unity was calculated for an equal size sample of ratios from independent, equal mean, symmetric distributions (p ratio >1 = 0.5, p ratio <1 =0.5). The rationale for the ratio test was that, among some replicate test data sets, a divergent gpm value was observed, and the resulting increase in variance for the small sample rendered a "not statistically significant" (at the 95%CL) assessment of the observed difference in mean emissions for the two fuels under comparison. The ratio test, being essentially an attributes test, was less sensitive to such divergent values and thus resulted in a statistically significant inference in cases where most gpm values with one fuel were lower than most gpm values from the comparison fuel.

The t-test comparison of means and the ratio test were each applied to both bag and RT gpm data for both vehicles, producing eight statistical inference results for each cycle/fuel comparison pair. Table B-1 presents the HC, CO, NO_x, and CO_2 95%CL t-test and ratio test statistical inferences for cycle/fuel comparisons in this study. The statistical inference symbols are :

+ = 95%CL inference fuel.1 emissions > fuel.2 emissions

– = 95%CL inference fuel.1 emissions < fuel.2 emissions
0 = t-test difference in means or ratio test result not significant at 95% CL

The shaded areas of Table B-1 indicate cycle/fuel comparisons wherein at least six of the eight statistical inferences are in agreement and any non-agreeing inferences are "0". Such comparisons, in our judgment, represent those fuel comparisons presenting, with 95% statistical confidence, a difference in gpm emissions and, consequently, at least the potential of some fuel effect on the applicable emissions. Due to confounding factors, however, we cannot state with certainty that any statistically significant difference observed is actually due to fuel effects.

We do note, however, for the EtOH/nonoxy/MTBE comparisons, in all such cases where six of the eight statistical tests are in agreement, that the inferred difference is " - ", implying emissions with either EtOH oxygenated or nonoxygenated gasolines are less than emissions with MTBE oxygenated gasoline at the 95%CL. Consequently, we infer the following:

> For any of these statistically significant emission differences that were, in fact, due to fuel effects, then the ethanol oxygenated RFG and the non-oxygenated ERFG resulted in **less** emissions than MTBE oxygenated RFG

Again, we caution that we cannot state than an effect due to fuel composition occurred, only that we infer the above directional result *if such an effect occurred.*

Considering the order of fuel testing (which was the same for each vehicle), the directional differences for the certification fuel at the start (Cert.start) and end (Cert.end) of testing on each vehicle pose a confounding factor in the assessment of emission changes with respect to the fuel used in testing. Note, for example, EtOH vs MTBE and nonoxy vs MTBE CO emissions in the Fuel Economy cycle, where we have inferred that CO emissions are less with EtOH and nonoxy gasoline than with MTBE gasoline. We see, for this cycle, that Achieva Cert.end CO emissions were, perhaps, slightly greater than Cert.start CO emissions and that Breeze Cert.end emissions were likely less than Cert.start emissions. If the Cert.end vs Cert.start emission difference represents a trend in vehicle emissions over the course of testing on each vehicle, then the EtOH and nonoxy vs MTBE emissions might have an imposed emission trend due to the Cert.end vs Cert.start trend as both EtOH and nonoxy fuel testing occurred *after* MTBE testing.

Thus, although Breeze CO emissions are less with EtOH fuel vs MTBE fuel, this effect may be due, at least in part, to a decreasing emission (Cert.end < Cert.start) trend over the course of testing the Breeze (possibly due to catalyst desulphurization) rather than due to a difference in fuel composition. For the Achieva, however, CO emissions increased slightly or remained the same over the course of testing, yet EtOH and nonoxy CO emissions were less than MTBE CO emissions, which, because EtOH and nonoxy testing occurred *after* MTBE testing, may run counter to the Cert.end > Cert.start trend, and, consequently, may imply a fuel effect.

Most importantly, however, note that the statistical inferences yield only a few instances where emissions with either EtOH fuel or nonoxy fuel are greater than emissions with MTBE fuel, and all such cases are for the Achieva with an associated increasing vehicle emission trend indicated by the Cert.end vs Cert.start comparison. Thus, we cautiously surmise that neither the EtOH nor nonoxy fuels pose a risk of significantly increased emissions vs the MTBE fuel for the two vehicles in this study.

Although we might interpret some of the data to indicate reductions in emissions for the EtOH and nonoxy fuels vs the MTBE fuel, we hesitate to stretch these data to that conclusion due to the small sample sizes and high risk of confounding factors.

Tables B-2, B-3, and B-4 provide quantitative fuel comparison statistics and other information re emissions for the composite FTP, highway fuel economy test (HFET), and US06 cycles.

The four left columns in Tables B-2 through B-4 identify the fuel pair comparison, the driving cycle (FTP indicates the FTP 3-bag composite), the vehicle, and the pollutant species. The next three columns indicate, respectively :

- the expected component directional change in emissions for the RFG fuels due to vehicle effects based on the assumption that the observed change in certification fuel emissions is monotonic over the vehicle test period
- the expected component directional change in emissions for the RFG fuels based on the Complex Model
- the observed directional emission change for the RFG fuels

The notation employed is :

" > " and " < "	indicate a statistically significant (95%CL) effect
" >= " and "<= "	indicate possible effect, but below 95% CL due to large sample variance and small sample size
" = "	indicates no statistically significant difference (95% CL)

In the right 4 columns, bag gpm data are given in the top row and realtime gpm data are given in the bottom row for each fuel comparison. The "range gpm" column provides the minimum and maximum gpm observations across both fuels (*i.e.*, minimum and maximum gpm without regard to fuel). The last 3 right columns present the mean difference (mean.fuel.1-meanfuel.2, mean delta) and the 95% upper and lower confidence limits (UCL, LCL) on the mean difference based on a t-test assumption of unequal sample variances.

Tables B-2 through B-4 permit subjective quantitative and qualitative assessments of emission differences with respect to :

(1) the emissions mean difference in terms of the absolute gpm emission level
(2) the 95% confidence range on the emissions mean difference
(3) potential impact the vehicle emission trend
(4) potential directional impact of fuel composition based on Complex Model theory

Table B-1

KEY:

symbols:

= - difference in fuels not significant at 95% CL
+ - fuel1 > fuel2, significant at 95% CL
− - fuel1 < fuel2, significant at 95% CL

First symbol - t-test comparison of means at 95% CL assuming unequal variances

second symbol - fuel1,i / fuel2,i ratio test, binomial probability ≤ 0.15 assuming equal means & symmetric distributions

Cert.start - certification fuel, start of testing on vehicle
Cert.end - certification fuel, end of testing on vehicle
EtOH - ethanol - oxygenate reformulated gasoline
MTBE - MTBE - oxygenate reformulated gasoline
nonoxy - non-oxygenated, reformulated gasoline

KhNOx - humidity adjusted NOx
NOx - NOx unadjusted for humidity

Order of Testing
1 Cert.start
2 MTBE
3 nonoxy
4 EtOH
5 Cert.end

5%CLFU MPARISO	Vehicle # Measureme	FTP BAG 1					FTP BAG 2					FTP BAG 3					FTP COMPOSITE				
		HC	CO	KhNOx	NOx	CO2	HC	CO	KhNOx	NOx	CO2	HC	CO	KhNOx	NOx	CO2	HC	CO	KhNOx	NOx	CO2
Cert.end vs Cert.sta	Achieva Ba	= +	+ +	+ +	+ +	na	+ +	+ +	+ +	+ +	− −	+ +	+ +	+ +	+ +	na	+ +	+ +	+ +	+ +	na
	Achieva RT	= +	+ +	+ +	+ +	= =	+ +	+ +	+ +	+ +	− −	+ +	+ +	+ +	+ +	= =	+ +	+ +	+ +	+ +	= −
	Breeze Bag	= =	= =	= =	= =	− −	− −	− −	= =	= =	= =	− −	− −	= =	= +	= −	= −	= −	= =	= =	− −
	Breeze RT	= =	= =	= =	= =	= =	− −	− −	= =	= =	= =	− −	− −	= =	= =	= =	= −	= −	= =	= =	= =
OH vs MT	Achieva Ba	= =	= =	= −	= =	= −	= −	= =	= −	= =	= −	= =	= =	− −	= =	− −	= +	= =	= −	= =	− −
	Achieva RT	= +	= =	= −	= =	− −	= +	= −	= −	= =	− −	= −	= =	= −	= =	− −	= +	= =	= −	= =	− −
	Breeze Bag	= =	= =	= =	= =	− −	− −	− −	− −	− −	= −	= −	− −	− −	− −	− −	= =	= =	= =	= =	− −
	Breeze RT	= =	= =	= =	= =	= =	= −	− −	− −	− −	= =	− −	− −	− −	− −	− −	= =	= =	= =	= =	= =
noxy vs M	Achieva Ba	= +	= +	= =	= =	= −	na	= =	= −	= =	= −	= =	= −	− −	= −	− −	na	= +	= −	= =	= −
	Achieva RT	= +	= +	= =	= =	= −	= =	= =	= =	= =	− −	= =	= =	− −	= −	− −	= +	+ +	= +	= =	− −
	Breeze Bag	= =	= =	= =	= =	− −	− −	− −	− −	− −	= −	= −	= =	= =	= −	− −	= =	= =	= =	= =	− −
	Breeze RT	= =	= =	= =	= =	= =	− −	− −	− −	− −	= =	= =	= =	= −	= −	= =	= =	= =	= =	= =	= =
noxy vs Et	Achieva Ba	= =	= +	= +	= =	= =	na	= +	= =	= =	= =	= =	= =	= −	= −	= =	na	+ +	= =	= −	= =
	Achieva RT	= =	= +	= +	= =	= =	= =	= +	= −	= −	= =	= +	= =	= −	= −	= =	= =	+ +	= =	= −	= =
	Breeze Bag	= =	= =	= =	= =	= =	= −	= =	= =	= =	= =	+ +	+ +	= =	= =	= =	= =	= =	= =	= =	= =
	Breeze RT	= =	= =	= =	= =	= =	− −	= =	= =	= =	= =	+ +	+ +	= =	= =	= =	= =	= =	= =	= =	= =

5%CLFU MPARISO	Vehicle # Measureme	FUEL ECONOMY					NYCC					US06				
		HC	CO	KhNOx	NOx	CO2	HC	CO	KhNOx	NOx	CO2	HC	CO	KhNOx	NOx	CO2
Cert.end vs Cert.sta	Achieva Ba	= =	= +	+ +	+ +	na	= +	= =	= =	= +	= −	+ +	+ +	= −	= =	na
	Achieva RT	= =	+ +	+ +	+ +	= =	= +	= =	= +	+ +	= −	+ +	+ +	= =	+ +	− −
	Breeze Bag	− −	− −	= =	= =	= =	= −	= =	= +	= +	= =	− −	− −	− =	= =	= −
	Breeze RT	− −	− −	= =	= =	= =	= =	= =	+ +	= +	= =	− −	= −	− −	− −	= =
OH vs MT	Achieva Ba	= −	= −	= −	= −	− −	= =	= =	= =	= =	− −	+ +	+ +	− −	− −	− −
	Achieva RT	= −	= −	− −	= −	− −	= =	= =	= =	= =	− −	+ +	+ +	− −	− −	− −
	Breeze Bag	= −	− −	− −	− −	= −	= =	= −	= −	= −	= =	= −	= −	− −	− −	= −
	Breeze RT	= −	− −	= −	= −	= −	= −	= −	= −	= −	= =	− −	= =	− −	− −	= −
noxy vs M	Achieva Ba	= −	− −	− −	− −	− −	= =	= =	= =	= =	= =	= =	= +	= −	= −	− −
	Achieva RT	= −	− −	− −	− −	− −	= =	= =	= =	= =	= =	= =	= +	= −	= =	− −
	Breeze Bag	= −	− −	= =	= =	− −	= −	= −	= =	= =	= =	= −	= =	− −	− −	− −
	Breeze RT	= =	− −	= =	= =	− −	= −	= −	= =	= =	= =	= −	= =	− −	− −	− −
noxy vs Et	Achieva Ba	= =	= −	= −	− −	= =	= =	= =	= =	= =	= =	= −	− −	+ +	+ +	= =
	Achieva RT	= −	= −	= −	= −	= =	= =	= =	= =	= =	= =	− −	− −	+ +	+ +	= +
	Breeze Bag	= =	= +	= +	= =	= =	= =	= =	= =	= =	= =	= =	= =	= =	= =	= =
	Breeze RT	= +	= +	= +	= +	= =	= =	= =	= =	= =	= =	= =	= =	= =	= =	= =

Table B-2

Fuel Pair	Cycle	Car	Pollutant	Predictions		Observed	bag	range	delta	mean delta	delta	% delta	% delta
				Car	Theory		realtime	gpm	UCL	gpm	LCL	low	high
C2 vs C1	FTP	Achieva	THC		C2=C1	C2>C1	bag	0.15 0.46	0.03	0.14	0.24	30%	90%
							realtime	0.15 0.45	0.03	0.13	0.23	28%	85%
ETOH vs MTBE	FTP	Achieva	THC	E>M	E>=M	E=M	bag	0.14 0.26	0.09	0.04	-0.02	13%	25%
							realtime	0.14 0.26	0.07	0.03	-0.01	12%	21%
Nonoxy vs MTBE	FTP	Achieva	THC	C>M	C>=M	C=M	bag	0.15 0.21	na	0.02	na	11%	15%
							realtime	0.15 0.35	0.14	0.05	-0.04	14%	33%
Nonoxy vs ETOH	FTP	Achieva	THC	C<E	C=E	C=E	bag	0.18 0.25	na	-0.01	na	-4%	-6%
							realtime	0.18 0.32	0.11	0.02	-0.07	6%	11%
C2 vs C1	FTP	Breeze	THC		C2=C1	C2<=C1	bag	0.20 0.30	-0.11	-0.05	0.02	-18%	-24%
							realtime	0.22 0.30	-0.09	-0.04	0.01	-13%	-17%
ETOH vs MTBE	FTP	Breeze	THC	E<=M	E>=M	E=M	bag	0.35 0.40	0.14	0.01	-0.12	3%	4%
							realtime	0.25 0.40	0.14	0.02	-0.10	6%	8%
Nonoxy vs MTBE	FTP	Breeze	THC	C<=M	C>=M	C=M	bag	0.28 0.40	0.14	-0.00	-0.14	-0%	-0%
							realtime	0.28 0.40	0.13	0.01	-0.12	1%	2%
Nonoxy vs ETOH	FTP	Breeze	THC	C>=E	C=E	C=E	bag	0.28 0.40	0.12	-0.01	-0.14	-3%	-4%
							realtime	0.28 0.40	0.11	-0.02	-0.13	-4%	-6%
C2 vs C1	HFET	Achieva	THC		C2=C1	C2=C1	bag	0.046 0.075	-0.02	0.00	0.02	3%	4%
							realtime	0.050 0.080	-0.01	0.00	0.02	6%	8%
ETOH vs MTBE	HFET	Achieva	THC	E=M	E>=M	E=M	bag	0.046 0.075	0.01	-0.01	-0.02	-6%	-15%
							realtime	0.035 0.075	0.01	-0.01	-0.04	-15%	-34%
Nonoxy vs MTBE	HFET	Achieva	THC	C=M	C>=M	C=M	bag	0.010 0.075	0.01	-0.02	-0.06	-32%	-240%
							realtime	0.010 0.075	0.00	-0.03	-0.06	-37%	-280%
Nonoxy vs ETOH	HFET	Achieva	THC	C=E	C=E	C=E	bag	0.010 0.060	0.02	-0.02	-0.05	-28%	-170%
							realtime	0.010 0.060	0.01	-0.02	-0.05	-27%	-180%
C2 vs C1	HFET	Breeze	THC		C2=C1	C2<C1	bag	0.020 0.060	-0.04	-0.03	-0.03	-57%	-170%
							realtime	0.020 0.060	-0.04	-0.03	-0.02	-66%	-165%
ETOH vs MTBE	HFET	Breeze	THC	E<M	E>=M	E=M	bag	0.030 0.078	0.01	-0.02	-0.04	-20%	-60%
							realtime	0.026 0.080	0.02	-0.02	-0.06	-28%	-88%
Nonoxy vs MTBE	HFET	Breeze	THC	C<M	C>=M	C=M	bag	0.036 0.078	0.01	-0.01	-0.03	-13%	-29%
							realtime	0.030 0.080	0.03	-0.01	-0.05	-14%	-43%
Nonoxy vs ETOH	HFET	Breeze	THC	C>E	C=E	C=E	bag	0.030 0.055	0.02	0.01	-0.01	9%	17%
							realtime	0.025 0.065	0.03	0.01	-0.01	14%	30%
C2 vs C1	US06	Achieva	THC		C2=C1	C2>C1	bag	0.075 0.275	0.04	0.34	0.21	125%	450%
							realtime	0.075 0.275	0.08	0.13	0.10	48%	175%
ETOH vs MTBE	US06	Achieva	THC	E>M	E>=M	E>M	bag	0.060 0.150	0.09	0.05	0.02	34%	85%
							realtime	0.060 0.150	0.09	0.04	0.01	29%	72%
Nonoxy vs MTBE	US06	Achieva	THC	C>M	C>=M	C=M	bag	0.060 0.130	0.06	0.01	-0.04	6%	13%
							realtime	0.060 0.130	0.05	0.00	-0.04	2%	5%
Nonoxy vs ETOH	US06	Achieva	THC	C<E	C=E	C<=E	bag	0.060 0.140	0.00	-0.04	-0.09	-31%	-72%
							realtime	0.060 0.140	-0.00	-0.04	-0.08	-28%	-68%
C2 vs C1	US06	Breeze	THC		C2=C1	C2<C1	bag	0.300 0.600	-0.28	-0.21	-0.14	-35%	-69%
							realtime	0.300 0.600	-0.28	-0.20	-0.12	-33%	-65%
ETOH vs MTBE	US06	Breeze	THC	E<M	E>=M	E<=M	bag	0.290 0.410	0.01	-0.06	-0.12	-14%	-20%
							realtime	0.300 0.420	-0.02	-0.06	-0.11	-15%	-21%
Nonoxy vs MTBE	US06	Breeze	THC	C<M	C>=M	C=M	bag	0.290 0.410	0.04	-0.04	-0.11	-9%	-12%
							realtime	0.310 0.420	0.03	-0.04	-0.11	-10%	-14%
Nonoxy vs ETOH	US06	Breeze	THC	C>E	C=E	C=E	bag	0.290 0.400	0.09	0.02	-0.04	6%	8%
							realtime	0.300 0.410	0.09	0.02	-0.05	5%	7%

Table B-3

Fuel Pair	Cycle	Car	Pollutant	Predictions		Observed	bag realtime	range gpm	delta UCL	mean delta gpm	delta LCL	% delta low	% delta high
				Car	Theory								
C2 vs C1	FTP	Achieva	CO		C2=C1	C2>C1	bag	3.0 6.0	0.80	1.76	2.70	29%	58%
							realtime	2.5 5.5	0.08	1.60	2.40	29%	64%
ETOH vs MTBE	FTP	Achieva	CO	E>M	E=M	E=M	bag	3.4 4.4	0.80	-0.02	-0.84	-0%	-1%
							realtime	3.0 3.8	0.40	0.02	-0.46	1%	1%
Nonoxy vs MTBE	FTP	Achieva	CO	C>M	C>M	C>=M	bag	3.4 5.2	1.48	0.64	-0.17	12%	10%
							realtime	3.0 4.6	1.30	0.67	0.03	15%	22%
Nonoxy vs ETOH	FTP	Achieva	CO	C<E	C>E	C>=E	bag	3.8 5.2	1.33	0.67	0.00	13%	18%
							realtime	3.0 4.6	1.29	0.64	0.01	14%	21%
C2 vs C1	FTP	Breeze	CO		C2=C1	C2<=C1	bag	1.2 2.8	-2.28	-0.84	0.60	-30%	-70%
							realtime	1.2 2.6	-2.11	-0.78	0.56	-30%	-65%
ETOH vs MTBE	FTP	Breeze	CO	E<=M	E=M	E=M	bag	1.5 5.0	1.56	-0.40	-2.36	-6%	-25%
							realtime	1.5 6.0	1.55	-0.37	-2.42	-7%	-25%
Nonoxy vs MTBE	FTP	Breeze	CO	C<=M	C>M	C=M	bag	1.6 6.0	1.76	-0.22	-2.19	-4%	-14%
							realtime	1.5 5.0	1.88	-0.18	-2.23	-4%	-12%
Nonoxy vs ETOH	FTP	Breeze	CO	C>=E	C>E	C=E	bag	1.5 3.5	1.46	0.16	-1.09	5%	12%
							realtime	1.5 3.6	1.54	0.21	-1.12	6%	14%
C2 vs C1	HFET	Achieva	CO		C2=C1	C2>=C1	bag	1.2 1.7	-0.07	0.16	0.40	10%	14%
							realtime	1.0 1.3	0.04	0.18	0.32	14%	19%
ETOH vs MTBE	HFET	Achieva	CO	E>=M	E=M	E<=M	bag	1.0 1.4	0.06	-0.16	-0.39	-12%	-16%
							realtime	0.7 1.1	0.03	-0.15	-0.34	-14%	-22%
Nonoxy vs MTBE	HFET	Achieva	CO	C>=M	C>M	C<M	bag	0.8 1.4	-0.11	-0.33	-0.56	-24%	-42%
							realtime	0.6 1.1	-0.05	-0.23	-0.42	-21%	-39%
Nonoxy vs ETOH	HFET	Achieva	CO	C<=E	C>E	C<=E	bag	0.8 1.2	0.02	-0.17	-0.36	-14%	-21%
							realtime	0.6 0.9	0.03	-0.08	-0.18	-9%	-13%
C2 vs C1	HFET	Breeze	CO		C2=C1	C2<C1	bag	0.4 2.0	-0.71	-1.03	-0.36	-62%	-269%
							realtime	0.4 2.0	-1.64	-0.99	-0.33	-49%	-247%
ETOH vs MTBE	HFET	Breeze	CO	E<M	E=M	E<M	bag	0.4 1.4	-0.51	-0.69	-0.87	-49%	-171%
							realtime	0.3 1.3	-0.51	-0.69	-0.87	-53%	-229%
Nonoxy vs MTBE	HFET	Breeze	CO	C<M	C>M	C<M	bag	0.5 1.4	-0.46	-0.60	-0.74	-43%	-119%
							realtime	0.4 1.3	-0.46	-0.59	-0.72	-46%	-146%
Nonoxy vs ETOH	HFET	Breeze	CO	C>E	C>E	C>=E	bag	0.4 0.8	0.27	0.09	-0.09	11%	22%
							realtime	0.3 0.7	0.28	0.10	-0.08	15%	34%
C2 vs C1	US06	Achieva	CO		C2=C1	C2>C1	bag	4.0 10.0	0.46	8.62	12.71	46%	216%
							realtime	4.0 16.0	5.24	7.77	10.29	49%	194%
ETOH vs MTBE	US06	Achieva	CO	E>M	E=M	E>M	bag	4.0 13.0	10.60	5.20	3.43	40%	130%
							realtime	3.0 11.0	6.16	4.51	2.86	41%	150%
Nonoxy vs MTBE	US06	Achieva	CO	C>M	C>M	C>=M	bag	4.0 7.0	2.80	1.12	-0.56	16%	28%
							realtime	3.5 6.6	2.71	0.97	-0.76	16%	28%
Nonoxy vs ETOH	US06	Achieva	CO	E<C	C>E	E<C	bag	5.0 12.5	-2.64	-4.08	-6.62	-33%	-82%
							realtime	4.5 11.0	-2.20	-3.53	-4.86	-32%	-78%
C2 vs C1	US06	Breeze	CO		C2=C1	C2<C1	bag	34 46	-13.74	-8.99	-4.25	-20%	-26%
							realtime	31 41	-10.17	-4.72	0.74	-12%	-16%
ETOH vs MTBE	US06	Breeze	CO	E<M	E=M	E=M	bag	24 36	2.63	-3.26	-9.06	-9%	-14%
							realtime	22 35	4.90	-2.33	-9.55	-7%	-11%
Nonoxy vs MTBE	US06	Breeze	CO	C<M	C>M	C=M	bag	30 37	5.36	0.28	-4.80	1%	1%
							realtime	28 36	6.76	1.44	-3.87	4%	5%
Nonoxy vs ETOH	US06	Breeze	CO	C>E	C>E	C=E	bag	24 37	9.77	3.65	-2.89	10%	15%
							realtime	22 36	-11.13	3.77	-3.69	10%	17%

Table B-4

Fuel Pair	Cycle	Car	Pollutant	Predictions Car	Predictions Theory	Observed	bag realtime	range gpm	delta UCL	mean delta gpm	delta LCL	% delta low	% delta high
C2 vs C1	FTP	Achieva	KhNOx		C2=C1	C2>C1	bag	0.55 0.95	0.20	0.27	0.34	28%	49%
							realtime	0.55 0.90	0.23	0.29	0.34	32%	52%
ETOH vs MTBE	FTP	Achieva	KhNOx	E>M	E<=M	E=M	bag	0.54 0.69	0.04	-0.05	-0.14	-7%	-9%
							realtime	0.50 0.62	0.03	-0.04	-0.10	-6%	-8%
Nonoxy vs MTBE	FTP	Achieva	KhNOx	C>M	C<M	C=M	bag	0.50 0.68	0.03	-0.06	-0.16	-9%	-13%
							realtime	0.46 0.62	0.02	-0.06	-0.14	-9%	-12%
Nonoxy vs ETOH	FTP	Achieva	KhNOx	C<E	C<=E	C=E	bag	0.50 0.68	0.07	-0.01	-0.10	-2%	-3%
							realtime	0.46 0.62	0.07	-0.02	-0.10	-3%	-4%
C2 vs C1	FTP	Breeze	KhNOx		C2=C1	C2=C1	bag	0.20 0.55	-0.39	-0.01	0.37	-1%	-4%
							realtime	0.25 0.60	-0.41	-0.02	0.37	-3%	-8%
ETOH vs MTBE	FTP	Breeze	KhNOx	E=M	E<=M	E=M	bag	0.19 0.35	0.07	-0.05	-0.16	-13%	-26%
							realtime	0.16 0.40	0.09	-0.04	-0.18	-11%	-20%
Nonoxy vs MTBE	FTP	Breeze	KhNOx	C=M	C<M	C=M	bag	0.20 0.34	0.06	-0.00	-0.07	-1%	-2%
							realtime	0.22 0.38	0.08	-0.01	-0.09	-1%	-2%
Nonoxy vs ETOH	FTP	Breeze	KhNOx	C=E	C<=E	C=E	bag	0.15 0.36	0.16	0.04	-0.07	12%	20%
							realtime	0.15 0.40	0.18	0.04	-0.10	10%	26%
C2 vs C1	HFET	Achieva	KhNOx		C2=C1	C2>C1	bag	0.50 0.90	0.26	0.31	0.35	34%	61%
							realtime	0.40 0.95	0.32	0.40	0.48	42%	90%
ETOH vs MTBE	HFET	Achieva	KhNOx	E>M	E<=M	E<=M	bag	0.40 0.56	0.01	-0.06	-0.12	-10%	-14%
							realtime	0.37 0.48	-0.03	-0.06	-0.08	-11%	-15%
Nonoxy vs MTBE	HFET	Achieva	KhNOx	C>M	C<M	C<M	bag	0.38 0.56	-0.02	-0.09	-0.15	-16%	-23%
							realtime	0.34 0.48	-0.04	-0.08	-0.12	-17%	-24%
Nonoxy vs ETOH	HFET	Achieva	KhNOx	C<E	C<=E	C=E	bag	0.38 0.48	0.01	-0.03	-0.08	-7%	-8%
							realtime	0.34 0.41	0.02	-0.03	-0.07	-5%	-8%
C2 vs C1	HFET	Breeze	KhNOx		C2=C1	C2=C1	bag	0.07 0.27	-0.08	0.07	0.20	24%	53%
							realtime	0.09 0.27	-0.09	0.04	0.17	16%	40%
ETOH vs MTBE	HFET	Breeze	KhNOx	E=M	E<=M	E<M	bag	0.06 0.20	-0.00	-0.06	-0.12	-29%	-67%
							realtime	0.07 0.22	0.01	-0.06	-0.13	-29%	-90%
Nonoxy vs MTBE	HFET	Breeze	KhNOx	C=M	C<M	C=M	bag	0.07 0.20	0.04	-0.02	-0.09	-12%	-35%
							realtime	0.07 0.22	0.04	-0.03	-0.10	-13%	-41%
Nonoxy vs ETOH	HFET	Breeze	KhNOx	C=E	C<=E	C>=E	bag	0.07 0.17	0.09	0.03	-0.03	19%	47%
							realtime	0.07 0.17	0.09	0.03	-0.02	20%	40%
C2 vs C1	US06	Achieva	KhNOx		C2=C1	C2<=C1	bag	1.80 2.30	-0.57	-0.28	0.00	-12%	-18%
							realtime	1.86 2.30	-0.26	0.00	0.26	0%	0%
ETOH vs MTBE	US06	Achieva	KhNOx	E<=M	E<=M	E<M	bag	1.10 2.10	-0.47	-0.73	-0.99	-35%	-66%
							realtime	1.10 1.90	-0.39	-0.53	-0.67	-28%	-48%
Nonoxy vs MTBE	US06	Achieva	KhNOx	C<=M	C<M	C<=M	bag	1.30 2.10	0.04	-0.30	-0.64	-14%	-23%
							realtime	1.30 1.85	0.19	-0.14	-0.46	-7%	-10%
Nonoxy vs ETOH	US06	Achieva	KhNOx	C>=E	C<=E	C>E	bag	1.10 1.86	0.75	0.43	0.11	23%	39%
							realtime	1.05 1.76	0.71	0.39	0.08	22%	37%
C2 vs C1	US06	Breeze	KhNOx		C2=C1	C2<C1	bag	0.30 0.47	-0.20	-0.10	-0.00	-22%	-34%
							realtime	0.29 0.47	-0.21	-0.12	-0.03	-26%	-41%
ETOH vs MTBE	US06	Breeze	KhNOx	E<M	E<=M	E<M	bag	0.25 0.46	-0.02	-0.13	-0.24	-29%	-52%
							realtime	0.25 0.46	-0.09	-0.14	-0.19	-30%	-55%
Nonoxy vs MTBE	US06	Breeze	KhNOx	C<M	C<M	C<M	bag	0.25 0.46	-0.03	-0.14	-0.24	-30%	-54%
							realtime	0.26 0.46	-0.09	-0.14	-0.19	-31%	-56%
Nonoxy vs ETOH	US06	Breeze	KhNOx	C>E	C<=E	C=E	bag	0.26 0.29	0.02	-0.01	-0.03	-2%	-2%
							realtime	0.25 0.30	0.03	-0.00	-0.03	-1%	-2%

APPENDIX C

DISCUSSION OF OBD II RESULTS

Data Collection and Analysis

Throughout the test program, tailpipe emissions data were supplemented with OBD II data to determine if there was any significant response to fuel characteristics not evident in the regulated pollutants.

OBD II data was collected using EASE Diagnostics PC Based Scan Tool software. The PC was connected directly to the vehicle's OBD II port through an EASE ST12-INT interface. A generic data set was selected for each vehicle. Data recording was manually controlled by reference to an audible signal produced by the driver's aid at the beginning and end of each cycle. A data file was saved at the end of each cycle to facilitate identification of the particular run. Following testing, the EASE data files were converted to comma delineated files and parsed into QuattroPro for analysis. Statistical analyses were performed with ProStat 2.0 software.

It was anticipated that the following parameters, available for both vehicles, would be of primary interest, with the indicated potential interpretation:

oxygen sensor voltage - oxygen sensor response
long term fuel trim - fuel injection frequency adjustment, deviation from normal
throttle opening - driver awareness of fuel characteristics.

This appendix presents typical graphs of the data collected by the OBD II scan tool used during all testing in this study. Other OBD II data are available upon request.

Figure C1 illustrates the effect of all four test fuels on long term fuel trim for the Plymouth Breeze when operated on the FTP cycle Bag 1. Moving to the right on the X-axis indicates longer injection times, or simply more fuel injected per intake cycle. The baseline fuel is the left most curve on the graph and the progression is the non-oxygenated ERFG fuel second from the left, the ethanol oxygenated RFG fuel second from the right and the MTBE oxygenated RFG fuel to the right. This illustrates that, as the fuels provide more oxygen, the feedback control system is able to enrichen the mixture while maintaining the desired levels of residual oxygen in the exhaust. The reduced energy content of the oxygenated fuels may compound this tendency toward enrichment.

Figure C1
Normalized Cumulative Frequency for Long Term Fuel Trim
for the Plymouth Breeze Operated on Bag 1 of the FTP for All Fuels

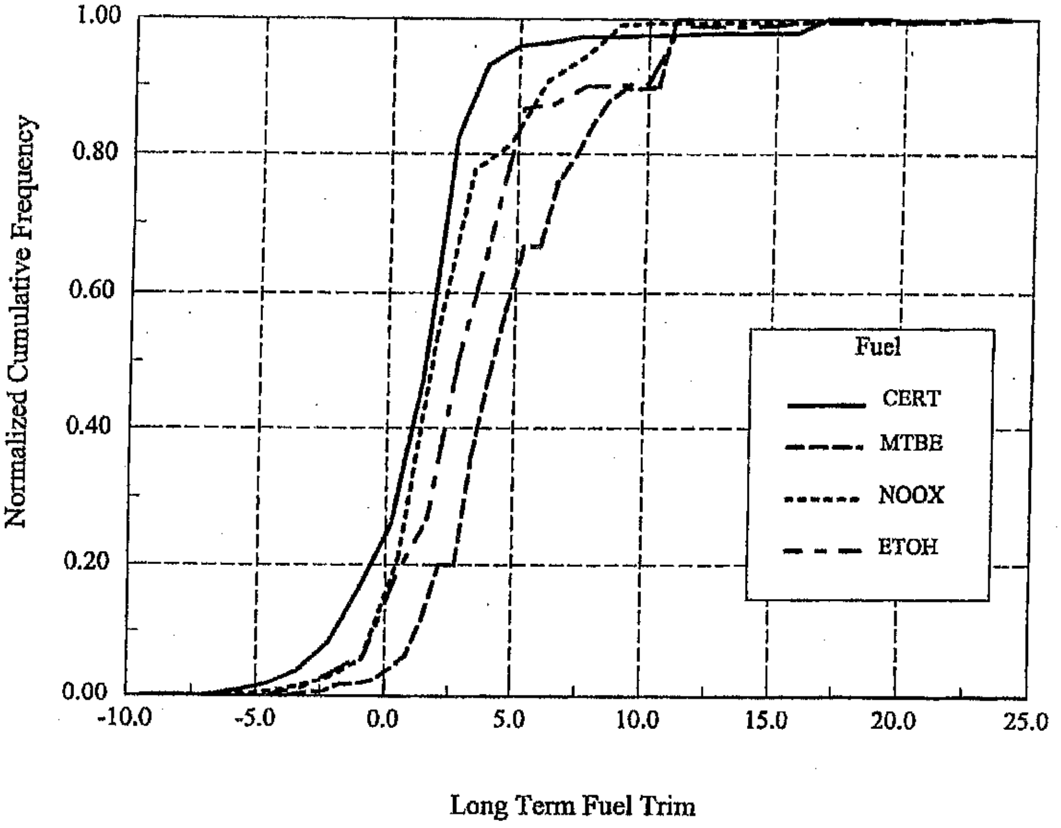
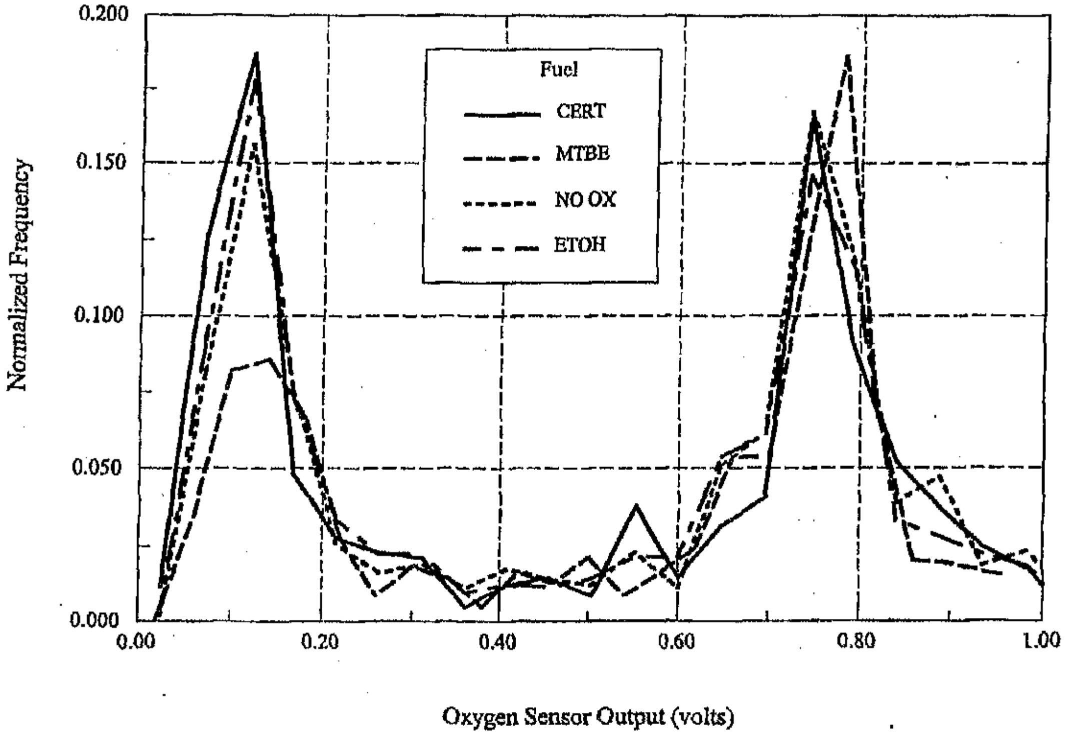


Figure C2 illustrates the response of the oxygen sensor for all four test fuels on the Plymouth Breeze when operated on the FTP Cycle Bag 1. Stoichiometric combustion occurs at approximately 0.5 volts for this vehicle. The bimodal distribution in Figure C2 demonstrates the constant dithering of the fuel management system between a rich and lean mixture to maintain optimal 3-way catalyst function. The important fact disclosed by this graph is that the feedback control system achieves residual oxygen levels that are essentially independent of the oxygen content of the fuel.

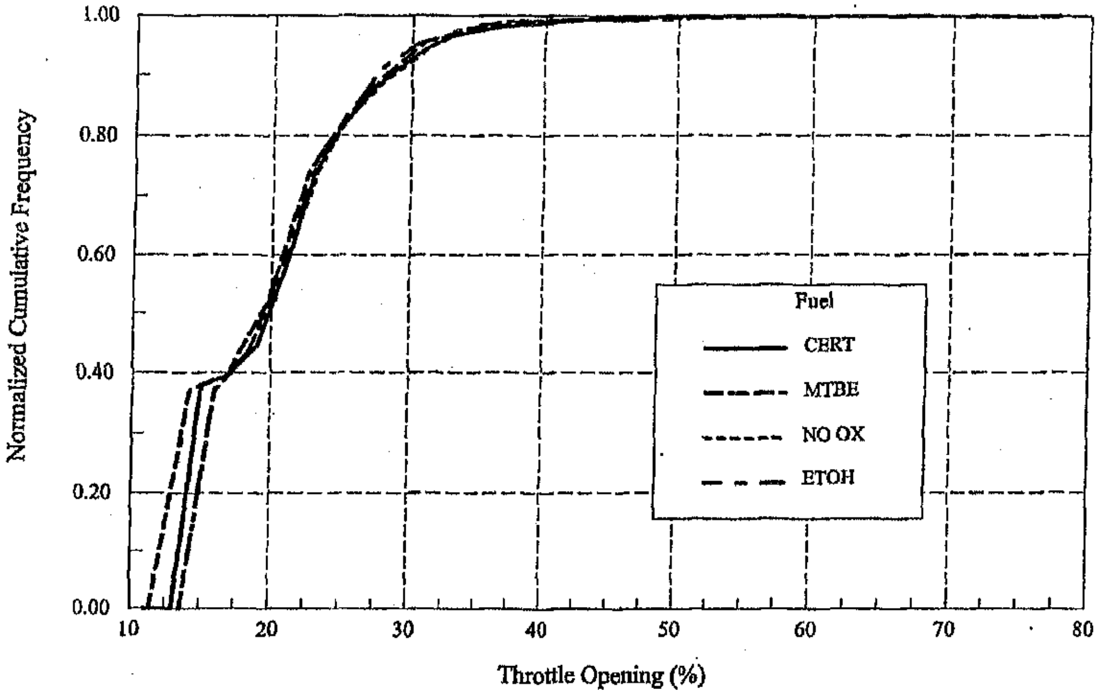
Figure C2
Normalized Frequency for Oxygen Sensor Output
for the Plymouth Breeze Operated on Bag 1 of the FTP for All Fuels



Together, Figures C1 and C2 suggest that oxygenated fuels have been rendered largely obsolete by modern feedback mixture controls. The additional oxygen content, desirable in carbureted engines, now permits enrichment of the mixture beyond levels experienced on certification fuel.

Below, Figure C3 shows that throttle position is essentially the same regardless of fuel type, thus the change in fuel composition would be transparent to the driver of the vehicle.

Figure C3
Normalized Cumulative Frequency of Throttle Opening
for the Plymouth Breeze Operated on the Bag 1 of the FTP for All Fuels



These results were fairly typical for all of the test cycles and all of the fuels tested in this program. We were able to determine that the engine management systems for both vehicles operated essentially the same, that fuel mixture control is dithered about stoichiometric AFR to optimize and maintain catalyst function.

Furthermore, throttle position sensor data suggest that fuel composition would be transparent to the driver of either vehicle. Throttle position for each vehicle was essentially the same for all four fuels on any specific test cycle, hence the driver should not feel a need to modify throttle operation across fuels to achieve desired vehicle performance.

APPENDIX D

EMISSION TESTING DATABASE

BAG GPM

REALTIME GPM

HC

CO

NO_X

CO_2

1997 OLDS ACHIEVA SL
CERT GASOLINE START

				bag gpm data					realtime gpm data				
date	test.id	cycle	driver	HC	CO	Kh,adj NOx	H unadj NOx	CO2	HC	CO	Kh,adj NOx	H unadj NOx	CO2
11/08/02	110802F	US06	PW	0.205	13.396	1.615	1.940	312.27	0.253	15.135	2.274	2.732	
10/01/02	100102A1	FTP Bag 1	DG	0.763	7.194	0.918	0.949		0.788	6.478	0.893	0.923	405.30
10/01/02	100102A2	FTP Bag 2	DG	0.035	2.028	0.450	0.465	446.82	0.025	1.641	0.425	0.439	411.21
10/01/02	100102B	FTP Bag 3	DG	0.084	2.543	0.743	0.777		0.071	2.212	0.670	0.700	347.45
10/01/02	100102D	Fuel Econ.	PW	0.051	1.238	0.539	0.561		0.052	1.039	0.523	0.545	274.79
10/01/02	100102H	NYCC	PW	0.282	8.920	1.446	1.492	795.23	0.302	7.716	1.283	1.324	670.08
10/01/02	100102I	US06	PW	0.085	6.119	2.289	2.360		0.091	5.711	2.186	2.253	380.31
10/02/02	100202A1	FTP Bag 1	DG	0.565	6.459	1.017	0.964		0.596	5.780	0.913	0.865	386.25
10/02/02	100202A2	FTP Bag 2	DG	0.037	2.309	0.480	0.454	435.44	0.028	1.912	0.465	0.441	401.47
10/02/02	100202B	FTP Bag 3	DG	0.078	2.573	0.818	0.757		0.085	2.297	0.745	0.689	340.75
10/02/02	100202C	Fuel Econ.	PW	0.057	1.322	0.544	0.499		0.059	1.014	0.533	0.489	265.10
10/02/02	100202D	NYCC	PW	0.196	6.462	1.032	0.942		0.169	5.422	0.980	0.894	651.66
10/02/02	100202E	US06	PW	0.158	8.615	2.048	1.856	543.11	0.164	8.018	2.024	1.834	362.62
10/03/02	100302A1	FTP Bag 1	DG	0.568	7.037	0.877	0.902		0.588	6.094	0.804	0.827	382.50
10/03/02	100302A2	FTP Bag 2	DG	0.042	2.539	0.393	0.404	436.05	0.034	2.067	0.414	0.426	403.70
10/03/02	100302B	FTP Bag 3	DG	0.089	2.630	0.693	0.715		0.077	2.231	0.626	0.646	346.00
10/03/02	100302C	Fuel Econ.	PW	0.067	1.418	0.526	0.555	284.86	0.069	1.050	0.468	0.493	267.20
10/03/02	100302D	NYCC	PW	0.226	8.074	1.042	1.122	704.57	0.201	6.621	0.982	1.057	654.70
10/03/02	100302E	US06	PW	0.088	4.889	2.124	2.309		0.119	6.274	1.988	2.161	367.70
10/04/02	100402A1	FTP Bag 1	DG	0.810	10.263	0.982	1.064	434.60	0.850	9.363	0.869	0.942	404.60
10/04/02	100402A2	FTP Bag 2	DG	0.049	2.946	0.398	0.431	442.24	0.044	2.375	0.396	0.429	415.60
10/04/02	100402B	FTP Bag 3	DG	0.091	3.076	0.702	0.767	373.33	0.095	2.601	0.617	0.674	352.10
10/04/02	100402C	Fuel Econ.	PW						0.060	1.044	0.430	0.467	266.90
10/04/02	100402D	NYCC	PW						0.239	7.680	0.895	0.973	654.50
10/04/02	100402E	US06	PW						0.081	4.750	1.892	2.087	361.50

1997 OLDS ACHIEVA SL
MTBE GASOLINE

				bag gpm data					realtime gpm data				
date	test id	cycle	driver	HC	CO	Kh..adj NOx	H.unadj NOx	CO2	HC	CO	Kh..adj NOx	H.unadj NOx	CO2
10/08/02	100802B1	FTP Bag 1	DG						0.688	6.828	0.818		412.50
10/08/02	100802B2	FTP Bag 2	DG	0.036	2.413	0.514	0.601	406.07	0.028	2.086	0.458	0.535	413.80
10/08/02	100802C	FTP Bag 3	DG	0.086	2.800	0.716	0.857	377.22	0.076	2.425	0.649	0.776	349.90
10/08/02	100802E	Fuel Econ.	PW	0.072	1.322	0.463	0.553	295.97	0.075	1.012	0.440	0.526	270.00
10/08/02	100802F	NYCC	PW	0.181	6.936	0.979	1.176	701.59	0.153	5.877	0.914	1.098	656.00
10/08/02	100802G	US06	PW	0.060	3.973	2.038	2.462	407.11	0.064	3.498	1.801	2.175	376.80
10/09/02	100902A1	FTP Bag 1	DG	0.788	9.935	0.901	1.066	433.23	0.817	8.924	0.791	0.935	397.90
10/09/02	100902A2	FTP Bag 2	DG	0.036	2.807	0.465	0.550	435.53	0.030	2.278	0.440	0.520	410.40
10/09/02	100902B	FTP Bag 3	DG	0.102	3.130	0.714	0.849	383.14	0.081	2.683	0.629	0.748	348.70
10/09/02	100902C	Fuel Econ.	PW	0.047	1.064	0.480	0.572	294.79	0.038	0.766	0.467	0.556	266.70
10/09/02	100902D	NYCC	PW	0.168	6.444	1.005	1.197	710.48	0.143	5.382	0.944	1.124	659.80
10/09/02	100902E	US06	PW	0.065	4.924	1.819	2.162	397.69	0.071	4.505	1.662	1.976	366.40
10/10/02	101002A1	FTP Bag 1	DG	0.574	6.924	0.876	0.948	425.28	0.606	6.173	0.795	0.861	392.60
10/10/02	101002A2	FTP Bag 2	DG	0.031	2.455	0.393	0.426	430.14	0.027	2.036	0.381	0.412	406.10
10/10/02	101002B	FTP Bag 3	DG	0.074	3.103	0.701	0.759	381.05	0.066	2.721	0.624	0.676	351.90
10/10/02	101002C	Fuel Econ.	PW	0.059	1.235	0.528	0.572	294.93	0.065	1.003	0.463	0.502	267.80
10/10/02	101002D	NYCC	PW	0.168	5.694	1.021	1.106	713.97	0.141	4.771	0.925	1.002	661.40
10/10/02	101002E	US06	PW	0.071	4.956	2.039	2.210	395.76	0.075	4.703	1.819	1.972	371.80
10/11/02	101102A1	FTP Bag 1	DG	0.639	8.188	1.063	1.145	428.93	0.670	7.216	0.944	1.017	396.70
10/11/02	101102A2	FTP Bag 2	DG	0.035	2.909	0.477	0.514	436.98	0.029	2.422	0.465	0.501	411.80
10/11/02	101102B	FTP Bag 3	DG	0.085	2.814	0.721	0.773	380.19	0.072	2.404	0.631	0.677	353.70
10/11/02	101102C	Fuel Econ.	PW	0.055	1.383	0.554	0.592	297.30	0.059	1.031	0.475	0.507	272.40
10/11/02	101102D	NYCC	PW	0.196	6.775	1.043	1.122	723.38	0.165	5.476	0.920	0.990	664.40
10/11/02	101102E	US06	PW	0.111	6.620	1.686	1.805	397.69	0.118	6.146	1.638	1.754	366.20

1997 OLDS ACHIEVA SL
NONOXY GASOLINE

				bag gpm data							altime gpm data			
date	test.id	cycle	drive	HC	CO	Kh_adj NOx	H.unadj NOx	CO2	HC	C		Kh_adj NOx	H.unadj NOx	CO2
10/15/02	101502A1	FTP Bag 1	DG	1.366	15.723	0.960	1.162	429.24	1.330	14.	7	0.865	1.047	403.60
10/15/02	101502A2	FTP Bag 2	DG		2.109	0.482	0.583	425.40	0.041	1.	2	0.503	0.609	405.30
10/15/02	101502C	FTP Bag 3	DG	0.049	2.865	0.605	0.730	369.45	0.078	2.	5	0.550	0.664	346.10
10/15/02	101502D	Fuel Econ.	PW	0.018	0.802	0.420	0.511	289.56	0.019	0.	8	0.396	0.481	266.40
10/15/02	101502E	NYCC	PW	0.100	4.022	1.168	1.419	723.97	0.086	3	5	1.028	1.249	672.80
10/15/02	101502F	US06	PW	0.060	6.787	1.556	1.909	394.64	0.065	6.	6	1.760	2.159	367.80
10/16/02	101602A1	FTP Bag 1	JM	0.783	11.017	0.848	0.955	423.37	0.790	9	5	0.751	0.846	379.70
10/16/02	101602A2	FTP Bag 2	JM	0.037	2.733	0.354	0.398	416.98	0.029	2	1	0.331	0.373	385.00
10/16/02	101602C	FTP Bag 3	JM	0.081	2.423	0.543	0.608	358.58	0.066	2	1	0.487	0.545	329.80
10/16/02	101602D	Fuel Econ.	PW	0.054	0.945	0.451	0.503	282.29	0.050	0	3	0.400	0.446	254.80
10/16/02	101602E	NYCC	PW	0.195	5.485	0.977	1.090	685.20	0.145	4	9	0.895	0.999	629.30
10/16/02	101602F	US06	PW	0.130	7.047	1.836	2.021	370.85	0.125	6	9	1.751	1.928	343.90
10/17/02	101702A1	FTP Bag 1	JM	0.791	10.509	0.926	1.056	414.13	0.813	9	0	0.835	0.952	375.40
10/17/02	101702A2	FTP Bag 2	JM		3.475	0.351	0.400	387.66	0.033	2	7	0.332	0.378	380.70
10/17/02	101702B	FTP Bag 3	JM	0.118	2.891	0.648	0.741	351.97	0.094	2	9	0.581	0.665	326.50
10/17/02	101702C	Fuel Econ.	PW	0.011	0.855	0.383	0.442	280.17	0.010	0	3	0.340	0.392	254.80
10/17/02	101702D	NYCC	JM	0.258	7.760	1.049	1.204	663.53	0.210	6	0	0.976	1.120	610.80
10/17/02	101702E	US06	JM	0.072	5.299	1.664	1.898	369.66	0.072	4	9	1.566	1.786	343.00
10/18/02	101802A1	FTP Bag 1	JM	0.668	9.667	0.899	1.057	416.63	0.710	8	5	0.812	0.955	386.00
10/18/02	101802A2	FTP Bag 2	JM		2.825	0.365	0.429	418.69	0.027	2	5	0.346	0.407	390.50
10/18/02	101802B	FTP Bag 3	JM	0.092	2.573	0.657	0.775	363.74	0.094	2	5	0.589	0.695	333.20
10/18/02	101802D	Fuel Econ.	Ri	0.054	1.068	0.421	0.497	282.32	0.044	0	1	0.387	0.456	259.30
10/18/02	101802E	NYCC	Di	0.240	10.639	0.871	1.027	678.61	0.184	9	2	0.824	0.972	633.90
10/18/02	101802F	US06	Di	0.080	5.819	1.314	1.552	376.17	0.078	5	5	1.299	1.534	346.20

1997 OLDS ACHIEVA SL
EtOH GASOLINE

				bag gpm data					realtime gpm data				
date	test.id	cycle	driver	HC	CO	Kh..adj NOx	H.unadj NOx	CO2	HC	CO	Kh..adj NOx	H.unadj NOx	CO2
10/22/02	102202A1	FTP Bag 1	DG		10.129	0.900	1.093	428.28	0.831	9.089	0.816	0.991	390.50
10/22/02	102202A2	FTP Bag 2	DG		2.446	0.313	0.381	419.43	0.030	1.965	0.385	0.468	393.50
10/22/02	102202B	FTP Bag 3	DG		2.736	0.694	0.844	373.24	0.072	2.320	0.640	0.779	342.40
10/22/02	102202C	Fuel Econ.	??		1.120	0.476	0.576	285.76	0.045	0.876	0.428	0.518	257.10
10/22/02	102202D	NYCC	Di		9.916	1.026	1.237	694.25	0.177	8.382	0.973	1.174	636.20
10/22/02	102202F	US06	Di		9.462	1.100	1.330	376.69	0.115	8.651	1.089	1.316	344.30
10/28/02	102802A1	FTP Bag 1	DG	0.894	8.019	0.874	1.048	412.04	0.897	7.147	0.781	0.937	379.70
10/28/02	102802A2	FTP Bag 2	DG	0.034	2.688	0.385	0.462	417.46	0.030	2.161	0.367	0.440	386.70
10/28/02	102802B	FTP Bag 3	DG	0.094	2.893	0.634	0.759	366.99	0.076	2.436	0.572	0.685	330.90
10/28/02	102802C	Fuel Econ.	JM	0.047	1.083	0.452	0.537	286.47	0.053	0.724	0.405	0.481	257.10
10/28/02	102802D	NYCC	JM	0.209	6.794	1.025	1.215	682.55	0.164	5.622	0.942	1.118	623.60
10/28/02	102802F	US06	JM	0.142	12.190	1.097	1.312	370.23	0.143	10.666	1.247	1.492	340.80
10/29/02	102902A1	FTP Bag 1	DG	1.001	10.524	0.926	1.141	438.68	1.006	9.478	0.819	1.009	393.10
10/29/02	102902A2	FTP Bag 2	DG	0.031	2.273	0.575	0.709	424.35	0.030	1.804	0.530	0.653	397.20
10/29/02	102902B	FTP Bag 3	DG	0.076	3.275	0.691	0.850	371.30	0.063	2.788	0.624	0.768	341.50
10/29/02	102902C	Fuel Econ.	Di	0.053	1.112	0.464	0.570	283.51	0.043	0.820	0.416	0.511	256.80
10/29/02	102902D	NYCC	Di	0.197	8.144	1.027	1.262	692.86	0.155	6.805	0.968	1.190	640.60
10/29/02	102902E	US06	Di	0.124	10.040	1.186	1.460	376.64	0.120	9.043	1.192	1.468	346.60
10/31/02	103102A1	FTP Bag 1	DG	0.755	8.511	0.767	0.957	417.86	0.760	7.471	0.701	0.874	375.80
10/31/02	103102A2	FTP Bag 2	DG	0.035	2.571	0.407	0.507	413.43	0.029	2.091	0.377	0.470	383.30
10/31/02	103102B	FTP Bag 3	DG	0.080	2.848	0.635	0.789	359.92	0.066	2.413	0.589	0.732	330.70
10/31/02	103102C	Fuel Econ.	??	0.045	1.059	0.411	0.510	284.01	0.037	0.796	0.375	0.466	253.20
10/31/02	103102D	NYCC	Bo	0.133	5.020	0.787	0.975	646.68	0.105	4.138	0.753	0.933	596.00
10/31/02	103102E	US06	Bo	0.105	9.414	1.164	1.440	371.08	0.105	8.393	1.188	1.469	339.60
11/01/02	110102A1	FTP Bag 1	DG	0.725	7.782	0.790	0.955	407.71	0.729	6.867	0.731	0.884	370.80
11/01/02	110102A2	FTP Bag 2	DG	0.035	2.431	0.371	0.449	407.99	0.030	1.984	0.354	0.428	378.50
11/01/02	110102B	FTP Bag 3	DG	0.076	2.812	0.672	0.810	352.61	0.063	2.429	0.612	0.738	325.20
11/01/02	110102C	Fuel Econ.	PW	0.057	1.067	0.452	0.543	279.34	0.058	0.774	0.412	0.494	252.50
11/01/02	110102D	NYCC	PW	0.160	5.124	0.953	1.141	674.58	0.123	4.287	0.882	1.055	616.00
11/01/02	110102G	US06	PW	0.142	10.469	1.276	1.541	364.91	0.144	9.339	1.290	1.558	330.10

1997 OLDS ACHIEVA SL
CERT GASOLINE END

				bag gpm data					realtime gpm data				
date	test id	cycle	driver	HC	CO	Kh..adj NOx	H.unadj NOx	CO2	HC	CO	Kh..adj NOx	H.unadj NOx	CO2
11/05/02	110502A1	FTP Bag 1	DG	1.054	10.910	1.347	1.634	428.16	1.040	9.908	1.333	1.617	390.70
11/05/02	110502A2	FTP Bag 2	DG	0.097	4.207	0.691	0.838	429.07	0.085	3.603	0.642	0.779	402.70
11/05/02	110502B	FTP Bag 3	DG	0.107	3.417	1.022	1.235	371.28	0.111	2.947	1.028	1.242	342.60
11/05/02	110502C	Fuel Econ.	Di	0.049	1.496	0.870	1.051	289.70	0.050	1.183	0.886	1.070	263.60
11/05/02	110502D	NYCC	Di	0.330	9.368	1.447	1.750	701.73	0.325	8.133	1.289	1.559	651.10
11/05/02	110502E	US06	Di	0.224	13.504	1.942	2.365	382.89	0.219	12.147	1.933	2.354	345.30
11/06/02	110602A1	FTP Bag 1	JM	1.601	13.185	1.292	1.536		1.546	11.800	1.287	1.530	364.00
11/06/02	110602A2	FTP Bag 2	JM	0.113	4.226	0.688	0.818	408.73	0.099	3.548	0.618	0.735	373.30
11/06/02	110602B	FTP Bag 3	JM	0.128	3.364	0.942	1.114		0.134	2.900	0.942	1.114	315.90
11/06/02	110602C	Fuel Econ.	PW	0.073	1.693	0.820	0.966		0.078	1.299	0.837	0.986	246.20
11/06/02	110602D	NYCC	PW	0.311	7.255	1.387	1.627	666.44	0.250	6.102	1.208	1.417	604.40
11/06/02	110602E	US06	PW	0.266	18.328	1.930	2.257	341.05	0.268	15.333	1.936	2.264	333.70
11/07/02	110702A1	FTP Bag 1	DG	0.897	10.660	1.306	1.677	421.60	0.903	9.639	1.308	1.680	383.80
11/07/02	110702A2	FTP Bag 2	DG	0.099	4.457	0.708	0.910	413.47	0.092	3.828	0.647	0.831	387.00
11/07/02	110702B	FTP Bag 3	DG	0.139	3.443	0.955	1.227	365.63	0.145	2.976	0.964	1.239	336.50
11/07/02	110702C	Fuel Econ.	PW	0.059	1.351	0.870	1.111	283.71	0.060	1.111	0.885	1.130	262.50
11/07/02	110702D	NYCC	PW	0.301	7.534	1.378	1.753	684.42	0.252	6.359	1.236	1.573	637.50
11/07/02	110702E	US06	PW	0.240	15.421	1.994	2.545	382.01	0.244	13.207	1.956	2.497	353.20
11/08/02	110802A1	FTP Bag 1	JM	1.010	10.693	1.283	1.600	421.74	1.027	9.781	1.271	1.584	383.80
11/08/02	110802A2	FTP Bag 2	JM	0.075	3.354	0.650	0.810	420.22	0.069	2.738	0.603	0.752	389.70
11/08/02	110802B	FTP Bag 3	JM	0.114	3.041	0.915	1.126	356.95	0.108	2.933	1.047	1.288	371.10
11/08/02	110802C	Fuel Econ.	PW	0.061	1.416	0.814	0.992	284.66	0.066	1.269	0.936	1.141	290.20
11/08/02	110802E	NYCC	PW										

1997 OLDS ACHIEVA SL
FTP COMPOSITE GPM

			bag gpm data					r ltime gpm data					
date	test id	fuel	HC	CO	Kh..adj NOx	H.unadj NOx	CO2	HC	C		Kh..adj NOx	H.unadj NOx	CO2
10/01/02	100102FTP	cert gasoline start	0.200	3.240	0.627	0.651		0.196	2.	1	0.589	0.611	392.48
10/02/02	100202FTP	cert gasoline start	0.158	3.243	0.684	0.643		0.162	2.	0	0.635	0.597	381.64
10/03/02	100302FTP	cert gasoline start	0.164	3.497	0.576	0.593		0.161	2.	8	0.553	0.569	383.46
10/04/02	100402FTP	cert gasoline start	0.218	4.501	0.603	0.655	421.70	0.225	3.	8	0.555	0.603	395.85
10/08/02	100802FTP	MTBE gasoline						0.178	3.	1	0.585		395.99
10/09/02	100902FTP	MTBE gasoline	0.210	4.371	0.624	0.739	420.68	0.207	3.	5	0.565	0.669	390.89
10/10/02	101002FTP	MTBE gasoline	0.155	3.559	0.578	0.625	415.66	0.158	3.	2	0.534	0.578	388.43
10/11/02	101102FTP	MTBE gasoline	0.174	3.978	0.665	0.716	419.71	0.174	3.	1	0.610	0.656	392.71
10/15/02	101502FTP	nonoxy gasoline		5.136	0.615	0.743	410.85	0.318	4.	9	0.591	0.715	388.71
10/16/02	101602FTP	nonoxy gasoline	0.204	4.367	0.508	0.572	402.24	0.197	3.	3	0.461	0.518	368.71
10/17/02	101702FTP	nonoxy gasoline		4.773	0.552	0.629	383.34	0.212	4.	4	0.505	0.576	364.71
10/18/02	101802FTP	nonoxy gasoline		4.179	0.557	0.655	403.12	0.188	3.	3	0.510	0.600	373.78
10/22/02	102202FTP	EtOH gasoline		4.116	0.539	0.655	408.57	0.207	3.	7	0.544	0.662	378.84
10/28/02	102802FTP	EtOH gasoline	0.228	3.846	0.554	0.665	402.51	0.222	3.	7	0.509	0.610	369.96
10/29/02	102902FTP	EtOH gasoline	0.244	4.258	0.680	0.837	412.75	0.241	3.	4	0.616	0.758	381.06
10/31/02	103102FTP	EtOH gasoline	0.197	3.879	0.544	0.678	399.65	0.191	3.	6	0.502	0.626	367.29
11/01/02	110102FTP	EtOH gasoline	0.189	3.644	0.541	0.653	392.74	0.184	3.	8	0.503	0.607	362.28
11/05/02	110502FTP	cert gasoline end	0.298	5.378	0.918	1.112	413.03	0.290	4.	8	0.891	1.079	383.73
11/06/02	110602FTP	cert gasoline end	0.426	5.847	0.883	1.048		0.409	5.	1	0.846	1.004	355.60
11/07/02	110702FTP	cert gasoline end	0.275	5.464	0.900	1.156	402.04	0.275	4.	9	0.871	1.119	372.49
11/08/02	110802FTP	cert gasoline end	0.279	4.787	0.854	1.060	403.16	0.278	4.	9	0.863	1.072	383.37

H BREEZE
NE START

cycle	driver
FTP Bag 1	DG
FTP Bag 2	DG
FTP Bag 3	DG
Fuel Econ.	DG
NYCC	DG
US06	DG
FTP Bag 1	JM
FTP Bag 2	JM
FTP Bag 3	JM
Fuel Econ.	PW
NYCC	PW
US06	PW
FTP Bag 1	DG
FTP Bag 2	DG
FTP Bag 3	DG
Fuel Econ.	PW
NYCC	DG
US06	DG
FTP Bag 1	JM
FTP Bag 2	JM
FTP Bag 3	JM
Fuel Econ.	JM
NYCC	JM
US06	JM

FOR PUBLICATION

UNITED STATES COURT OF APPEALS FOR THE NINTH CIRCUIT

OXYGENATED FUELS ASSOCIATION INCORPORATED, *Plaintiff-Appellant,* v. GRAY DAVIS, in his capacity as Governor of the State of California; AIR RESOURCES BOARD, Alan C. Lloyd, in his capacity as Chairman of the California Air Resources Board, *Defendants-Appellees.*	No. 01-17078 D.C. No. CV-01-00156-DFL OPINION

Appeal from the United States District Court
for the Eastern District of California
David F. Levi, District Judge, Presiding

Argued and Submitted
February 11, 2003—San Francisco, California

Filed June 4, 2003

Before: William C. Canby, Jr., Diarmuid F. O'Scannlain and
William A. Fletcher, Circuit Judges.

Opinion by Judge William A. Fletcher

COUNSEL

Frederick R. Anderson and Geraldine Edens, Cadwalader, Wickersham & Taft, Washington, D.C., Rebecca Ceniceros and Gene Livingston, Livingston & Maattesich, Sacramento, California, for the appellant.

Russell B. Hildreth, Office of the Attorney General, Sacramento, California, Marc N. Melnick, Office of the Attorney General, Oakland, California, for the appellees.

OPINION

W. FLETCHER, Circuit Judge:

Plaintiff-appellant Oxygenated Fuels Association Inc. ("OFA") sued various state officials after California enacted a ban on methyl tertiary-butyl ether ("MTBE"), an oxygenate used to reduce gasoline emissions. OFA, a trade association representing MTBE producers, argued that California's MTBE ban is preempted by the federal Clean Air Act, 42 U.S.C. § 7401 *et seq.*, and sought to enjoin the ban. The defendants filed a motion to dismiss, which was granted by the district court.

We affirm. We conclude that, in enacting the Clean Air Act, Congress left the states substantial authority to enact legislation governing matters of public health and safety. Though the MTBE ban is not expressly exempted from preemption by the Clean Air Act, the ban nonetheless is not preempted because it does not conflict with the goals and purposes of the Clean Air Act.

I. Background

Congress enacted the Clean Air Act "to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." *Id.* § 7401(b)(1). The Act includes a variety of provisions aimed at reducing air pollution. Implementation and enforcement responsibilities under the Clean Air Act are shared between the federal government and state governments. For example, the EPA has the authority to set national ambient air quality standards, *see id.* § 7409, while the states have the authority to devise implementation plans to meet those standards, *see id.* § 7410.

One of the specific aims of the Clean Air Act is to reduce air pollution by reducing motor vehicle emissions. Section 211 of the Act, codified at 42 U.S.C. § 7545, sets forth the statutory framework for regulating motor vehicle fuels and fuel additives to achieve that aim. Among other things, § 211 requires that gasoline sold in certain areas of the country have an oxygen content that equals or exceeds 2.0 percent by weight. *Id.* § 7545(k)(2)(B). Section 211 further requires that, during the winter months, gasoline sold in certain areas have an oxygen content that equals or exceeds 2.7 percent by weight. *Id.* § 7545(m)(2)(B).

In order to meet the Clean Air Act's oxygen content requirements, gasoline manufacturers add oxygenate fuel additives to gasoline. MTBE and ethanol are the two most widely used oxygenates. California determined that, while MTBE reduces air pollution from motor vehicle emissions, it also causes substantial and deleterious groundwater pollution. In response to concerns about groundwater pollution, the California Air Resources Control Board decided to ban the use of MTBE as a fuel additive. *See* Cal. Code Regs. tit. 13, § 2262.6 (2003). The ban, adopted on December 9, 1999, was originally scheduled to take effect on December 31, 2002. The effective date has since been postponed for one year.

On May 4, 2001, OFA filed suit in the district court seeking to enjoin California's MTBE ban. OFA argued, among other things, that the ban conflicts with the objectives of the Clean Air Act and is therefore preempted. The defendants moved to dismiss the case under Rule 12(b)(6). Ruling that California is expressly exempted from Clean Air Act preemption, the district court granted the motion. *Oxygenated Fuels Ass'n v. Davis*, 163 F. Supp. 2d 1182, 1186-87 (E.D. Cal. 2001). The district court also held, in the alternative, that, even if not expressly exempted, California's MTBE ban is in any event not impliedly preempted by the Act. *See id.* at 1187-88. OFA appeals.

"We review *de novo* a dismissal under Fed. R. Civ. P. 12(b)(6) for failure to state a claim. In such a case, we must accept all factual allegations of the complaint as true and draw all reasonable inferences in favor of the nonmoving party." *TwoRivers v. Lewis*, 174 F.3d 987, 991 (9th Cir. 1999) (citation omitted).

II. Discussion

A. Background

Under Article VI of the Constitution, laws of the federal government "shall be the supreme Law of the Land; . . . any Thing in the Constitution or Laws of any State to the Contrary notwithstanding." Art. VI, cl. 2. Congress has the authority, when acting pursuant to its enumerated powers, to preempt state and local laws. The Supreme Court has recognized three types of preemption: express preemption, field preemption, and conflict preemption:

> First, Congress can define explicitly the extent to which its enactments pre-empt state law . . . .
>
> Second, in the absence of explicit statutory language, state law is pre-empted where it regulates conduct in a field that Congress intended the Federal Government to occupy exclusively. . . .
>
> Finally, state law is pre-empted to the extent that it actually conflicts with federal law. Thus, the Court has found pre-emption where it is impossible for a

> private party to comply with both state and federal requirements, or where state law "stands as an obstacle to the accomplishment and execution of the full purposes and objectives of Congress."

English v. Gen. Elec. Co., 496 U.S. 72, 78-79 (1990) (quoting *Hines v. Davidowitz*, 312 U.S. 52, 67 (1941)) (other citations omitted). Field preemption and conflict preemption are both forms of implied preemption. *See Lorillard Tobacco Co. v. Reilly*, 533 U.S. 525, 541 (2001).

"Congressional purpose is the 'ultimate touchstone' " of preemption analysis." *Id.* (quoting *Cipollone v. Liggett Group, Inc.*, 505 U.S. 504, 516 (1992)). Because it is assumed that Congress does not cavalierly decide to override state authority, there is a general presumption against preemption in areas traditionally regulated by states. "[W]e start with the assumption that the historic police powers of the States were not to be superseded by the Federal Act unless that was the clear and manifest purpose of Congress." *Rice v. Santa Fe Elevator Corp.*, 331 U.S. 218, 230 (1947). Preemption analysis requires a close examination of the particular statutes and regulations at issue. "[E]ach case turns on the peculiarities and special features of the federal regulatory scheme in question." *City of Burbank v. Lockheed Air Terminal, Inc.*, 411 U.S. 624, 638 (1973).

B. Express Exemption from Preemption

[1] The defendants argue that California's MTBE ban is expressly exempted from preemption under the Clean Air Act. The Clean Air Act contains both an express preemption provision regarding the regulation of oxygenate fuel additives and an express statutory exemption for California from the preemption provision. Generally, "no State (or political subdivision thereof) may prescribe or attempt to enforce, for purposes of motor vehicle emission control, any control or prohibition respecting any characteristic or component of a fuel or fuel additive in a motor vehicle or motor vehicle engine." 42 U.S.C. § 7545(c)(4)(A). California, however, "may at any time prescribe and enforce, *for the purpose of motor vehicle emission control*, a control or prohibition respecting any fuel or fuel additive." *Id.* § 7545(c)(4)(B) (the "(c)(4)(B) exemption") (emphasis added). The defendants argue that California's MTBE ban falls squarely within the (c)(4)(B) exemption. OFA argues that the MTBE ban is not exempted because it is not "for the purpose of motor vehicle emission control."

OFA claims that California did not adopt the MTBE ban to control motor vehicle emissions, or for any other reason related to air pollution. Rather, it adopted the ban to protect groundwater. The defendants do not really dispute this claim. They argue, however, that the ban fits within the (c)(4)(B) exemption because the ban is part of its overall "emissions control regulatory scheme" and that the scheme, as a whole, largely has the purpose of emissions control. The disagreement between the parties on this point thus turns to a substantial extent on whether the object of preemption analysis is (1) the MTBE ban itself, or (2) California's comprehensive emissions regulatory scheme of which the ban is just one part.

There is no obvious answer to this question, but the Supreme Court's approach in analogous cases offers some guidance. In *Pacific Gas & Electric Co. v. State Energy Resources Conservation & Development Commission*, 461 U.S. 190 (1983), the Supreme Court addressed California's moratorium on the construction of nuclear power plants. Energy companies had challenged the moratorium, arguing that it was preempted by the federal Atomic Energy Act ("AEA"). The AEA contained a preemption provision that preserved states' power "to regulate activities for purposes other than protection against radiation hazards." *Id.* at 210 (quoting 42 U.S.C. § 2021(k)). The Supreme Court concluded that Congress had taken "complete control of the safety and 'nuclear' aspects of energy generation," while leaving other aspects to states. *Id.* at 212. Whether the moratorium was preempted—that is, whether it fell within the AEA's express preemption provision—depended on whether it had a "nonsafety rationale." *Id.* at 213. In answering this question, the Supreme Court did not analyze California's plant-building moratorium as part of a larger energy control regulation or as part of an overall approach to energy policy. Rather, it analyzed the moratorium as a stand-alone provision, and it ruled that the moratorium itself had a nonsafety rationale and was therefore not preempted.

In *Department of Treasury v. Fabe*, 508 U.S. 491 (1993), the Supreme Court attempted to define the scope of a preemption exemption provision in federal bankruptcy law:

> The federal priority statute accords first priority to the United States with respect to a bankrupt debtor's obligations. An Ohio statute confers only fifth priority upon claims of the United States in proceedings to liquidate an insolvent insurance company. The federal priority statute pre-empts the inconsistent Ohio law unless the latter is exempt from preemption . . . . In order to resolve this case, we must decide whether a state statute establishing the priority of creditors' claims in a proceeding to liquidate an insolvent insurance company is a law enacted "for the purpose of regulating the business of insurance" . . . .

Id. at 493 (citations omitted). The Court held that Ohio's prioritizing of policyholders was "for the purpose of regulating the business of insurance," and so was not preempted, because the relationship between insurance companies and their policy holders was central to the business of insurance. *See id.* at 501. On the other hand, Ohio's attempt to prioritize other creditors' claims was preempted, because those provisions were not central to regulating the business of insurance, and were instead "designed to further the interests of other creditors." *Id.* at 508. As in *PG&E,* the Court did not analyze Ohio's bankruptcy priority rules as part of an overall approach to regulating insurance, but analyzed the rules themselves to see if, individually, they were for the purpose of regulating insurance. Indeed, the Court even analyzed different elements of the priority law separately, striking down one provision as preempted while allowing another.

[2] The Supreme Court's approach in *PG&E* and *Fabe* suggests that the relevant object of our preemption analysis is the MTBE ban itself, not California's overall emissions regulatory scheme. If we must decide whether the ban itself was enacted "for the purpose of motor vehicle emission control," 42 U.S.C. § 7545(c)(4)(B), the obvious answer is that it was not. Despite the simplicity of this suggested analysis, we nevertheless regard the exemption issue as a fairly close question. When Congress exempted California from the express preemption, it clearly intended to allow California substantial latitude in regulating, and choosing among, fuel additives under the (c)(4)(B) exemption. Surely, when acting within the exemption to choose among different oxygenates, California can consider—indeed, can give substantial weight to—factors other than the effects of those oxygenates on air pollution. But in this case, OFA has alleged that California adopted the MTBE ban specifically and solely for the purpose of protecting ground and drinking water. We therefore conclude, on a motion to dismiss under Rule 12(b)(6), that the ban does not come within the (c)(4)(B) exemption from preemption.

[3] We note that our ruling comports with the decisions of other federal courts that have considered this issue. *See Oxygenated Fuels Ass'n v. Pataki,* 158 F. Supp. 2d 248, 254 (N.D.N.Y. 2001) (holding that New York's MTBE law is "aimed at preventing groundwater pollution" and "is not a control or prohibition respecting any characteristic or component of a motor vehicle fuel or fuel additive for purposes of motor vehicle emission control"); *In re MTBE Prod. Liab. Litig.,* 175 F. Supp. 2d 593, 612 (S.D.N.Y. 2001) (holding that state lawsuits about MTBE contamination "concern[ed] groundwater contamination" and were "*not* brought for purposes of regulating motor vehicle emissions control"). In concert with these rulings, we hold that California's MTBE ban was not enacted for the purpose of emission control and therefore is not expressly exempted from preemption under Section 211(c)(4)(B) of the Clean Air Act.

C. Conflict Preemption

[4] OFA does not argue that California's MTBE ban is expressly preempted by the Clean Air Act. The reason for this is simple: the language of the Section 211(c)(4)(A) express preemption provision parallels the language of the (c)(4)(B) exemption. Under the (c)(4)(A) preemption provision, other states may not enforce a fuel control provision *for the purpose of emission control*, but under the (c)(4)(B) exemption, California may. *See* 42 U.S.C. § 7545(c)(4)(A)-(B). The two provisions are precisely coextensive. Therefore, because California's MTBE ban does not fit within the (c)(4)(B) exemption provision, it also does not fit within the (c)(4)(A) provision and is not expressly preempted.

OFA does argue, however, that the ban is impliedly preempted because it conflicts with the goals of the Clean Air Act. " '[A]n express definition of the pre-emptive reach of a statute . . . supports a reasonable inference . . . that Congress did not intend to pre-empt other matters.' " *Lorillard*, 533 U.S. at 541 (quoting *Freightliner Corp. v. Myrick*, 514 U.S. 280, 288 (1995)). Our holding that California's MTBE ban is not expressly preempted under (c)(4)(A) nevertheless does not "entirely foreclose[ ] any possibility of implied preemption." *Freightliner*, 514 U.S. at 288.

In support of its contention that California's MTBE ban is impliedly preempted, OFA offers two different but related arguments about how the ban "stands as an obstacle to the accomplishment and execution of the full purposes and objectives of Congress." *Hines*, 312 U.S. at 67. First, OFA argues that, in enacting the Clean Air Act, Congress intended to give gasoline producers an unrestricted choice among oxygenate fuel additives. Second, OFA argues that Congress meant to ensure an adequate and reasonably priced supply of oxygenated gasoline, and that California's MTBE ban will substantially disrupt the gasoline market and cause an increase in prices. We address these arguments in turn.

1. Oxygenate Neutrality

According to OFA, California's MTBE ban conflicts with the Act because it interferes with the marketplace and limits the choices of gasoline producers. OFA argues that a principle of "oxygenate neutrality" inheres in the Clean Air Act and that Congress intended to leave the choice of gasoline additives to the marketplace and gasoline producers. We find OFA's argument unpersuasive.

[5] The Clean Air Act generally seeks to preserve state authority. It declares "that air pollution prevention . . . and air pollution control at its source is the primary responsibility of States and local governments." 42 U.S.C. § 7401(a)(3). It states that its goals are "to encourage and assist the development and operation of regional air pollution prevention and control programs," *id.* § 7401(b)(4), and "to encourage or otherwise promote reasonable Federal, State, and local governmental actions, consistent with the provisions of this chapter, for pollution prevention," *id.* § 7401(c). The Act's savings provision provides a substantial retention of State authority. *See id.* § 7416. Finally, the Act explicitly contemplates that California can, in some instances, place restrictions on fuel additives. *See id.* § 7545(c)(4)(B).

OFA cites legislative history suggesting that Congress did not want the federal government to interfere with refiners' choices of additives. We hesitate to examine the legislative history, for we find the text of the Act relatively clear. Further, even if we do look to the history cited by OFA, it is composed primarily of statements of individual legislators. In analyzing legislative history, committee reports are "the authoritative source for finding the Legislature's intent," and statements of individual legislators are given much less weight. *Garcia v. United States*, 469 U.S. 70, 76 (1984). Finally, to the extent that we give weight to these statements, they evince nothing more than a congressional desire that the *federal government and the EPA* remain neutral among additives. There is no clear history indicating that Congress intended that the *states* remain neutral when they, for example, enact water pollution measures.

[6] Indeed, we have already substantially rejected the argument made here by OFA. "The legislative history [of the Clean Air Act] suggests that fuel neutrality on the part of the [EPA] Administrator was a goal of the provisions but all the references to state authority support the determination that state authority to regulate oxygenate levels was not thereby limited." *Exxon Mobil Corp. v. EPA*, 217 F.3d 1246, 1253 (9th Cir. 2000). In *Exxon Mobil,* we ruled on a challenge to Nevada's plan "to require a 3.5 percent minimum oxygen content for wintertime gasoline." *Id.* at 1248. As a practical matter, MTBE may not be blended in gasoline at a level greater than 2.7 percent. *See* Nevada State Implementation Plan Revision, Clark County, 64 Fed. Reg. 29,573, 29,575 n.3 (June 2, 1999). Consequently, Nevada's plan effectively banned the use of MTBE during the winter months. Exxon Mobil sued, arguing that Nevada's plan violated the Act's purpose of ensuring oxygenate neutrality, and that the plan was therefore preempted.

We rejected Exxon Mobil's argument. We noted that the Senate had originally proposed a 3.1 percent oxygen requirement for certain areas, but later reduced the requirement to 2.7 percent to allow for the use of MTBE, *see Exxon Mobil,* 217 F.3d at 1251, with an explanation by some Senators, however, that the Act still allowed states to adopt a higher requirement, *see id.* at 1251-53. Our analysis in *Exxon Mobil* mirrored the EPA's own analysis: the EPA had also concluded that congressional sentiments on fuel neutrality "address[ed] limitations on EPA's, not states', authority to choose between oxygenates." Nevada State Implementation Plan Revision, Clark County, 64 Fed. Reg. at 29,575. *See also id.* at 29,576-79 (discussing preemption claims).

OFA also argues that the Supreme Court's ruling in *Geier v. American Honda Motor Co.*, 529 U.S. 861 (2000), supports a holding that the Clean Air Act leaves the choice of oxygenates to gasoline producers. In *Geier*, the Supreme Court considered whether a lawsuit arising out of an automobile accident and premised on state tort law was preempted by the Department of Transportation's Federal Motor Vehicle Safety Standard ("FMVSS"). The lawsuit essentially sought to create, and then to rely on, a state common-law standard requiring airbags in all passenger cars. *See id.* at 865. The Supreme Court held that such a state-law requirement was preempted by the FMVSS. According to the Court, the FMVSS "deliberately provided the manufacturer with a range of choices among different passive restraint devices." *Id.* at 875.

Geier is distinguishable from this case on two grounds. First, in *Geier*, the relevant regulating agency, in interpreting its own governing statute, had decided that the suit was preempted, and the Supreme Court gave deference to the agency's determination. *See id.* at 883-84. Here the EPA has made no such determination. Second, the Supreme Court in *Geier* found abundant evidence in the administrative history of the FMVSS to indicate that it was intended to give auto manufacturers a choice of safety restraints. *See id.* at 875-83. We can find no evidence that the Clean Air Act was intended to give gasoline producers a comparable choice of oxygenates. Indeed, we have already specifically held in *Exxon Mobil* that the legislative history of the Clean Air Act does not support a conclusion that Congress meant to give gasoline producers an unconstrained choice of oxygenates. For these reasons, several courts have already rejected *Geier*-based preemption challenges to MTBE regulations. *See Abundiz v. Explorer Pipeline Co.*, 2002 U.S. Dist. LEXIS 13120 at *10-17 (N.D. Tex. July 17, 2002) (holding that *Geier* does not compel a finding that state MTBE regulations are preempted); *In re MTBE Litig.*, 175 F. Supp. 2d at 614-16 (same); *Pataki*, 158 F. Supp. 2d at 260 n.6 (same). *But see Holton v. Chevron U.S.A.*, 2001 U.S. Dist. LEXIS 17599 at *10 (D.N.J. July 3, 2001) (contra).

[7] We conclude that there is no conflict between the Clean Air Act and California's MTBE ban. Neither the text nor the legislative history of the Clean Air Act provides clear evidence that the ban conflicts with a congressional goal of oxygenate neutrality. There is some evidence that the EPA is required to be neutral, but there is none that the states must also be neutral.

2. Market Disruption

OFA also argues that California's MTBE ban is preempted because it will disrupt the market for gasoline. OFA alleges in its complaint that gasoline producers will be unable to obtain sufficient supplies of other oxygenates, and that gasoline prices will rise as supplies shrink. On a motion to dismiss under Rule 12(b)(6), we accept as true OFA's factual allegations.

We have already accepted OFA's allegation that the MTBE ban was enacted for the purpose of protecting groundwater, not for the purpose of regulating motor vehicle emissions. In analyzing conflict preemption, however, we examine not only the purpose of the MTBE ban; we also examine its effects. "Whatever the purpose or purposes of the state law, preemption analysis cannot ignore the effect of the challenged state action on the pre-empted field." *Gade v. Nat'l Solid Wastes Mgmt. Ass'n*, 505 U.S. 88, 107 (1992). Thus, even though the Clean Air Act and the MTBE ban operate in different areas—one protects air and the other protects water—we must nonetheless decide whether the effects of the latter interfere with the goals of the former.

The central goal of the Clean Air Act is to reduce air pollution. *See* 42 U.S.C. § 7401(b). OFA does not argue that California's MTBE ban will inhibit federal efforts to fight air pollution. It argues, rather, that a smoothly functioning gasoline market and inexpensive gasoline are also goals of the Clean Air Act, and that the ban will disrupt that market and cause high prices. OFA has offered virtually no support for its assertion that the Clean Air Act's goals—for purposes of preemption analysis—were a smoothly functioning gasoline market and cheap gasoline. It is questionable whether a smoothly functioning gasoline market should be considered a "goal" of the Clean Air Act; the statutory text describing the purposes of the Act mentions no such goal. *See id.* We take it as true that Congress wanted to reduce pollution caused by motor vehicles, but at the same time did not want to harm the nation's economy by causing gasoline prices to rise too much. But saying that Congress might not have wanted to cause a substantial increase in gasoline prices is not the same as saying that assuring inexpensive gasoline was a goal of the Act.

We are required to presume that Congress did not intend to preempt areas of law that fall within the traditional exercise of the police powers of the states. *Rice*, 331 U.S. at 230. Environmental regulation is an area of traditional state control. *See Exxon Mobil*, 217 F.3d at 1255. Only where there is "clear evidence" that Congress meant to assert federal control should we find that state action is preempted. *Geier*, 529 U.S. at 885. There is no such evidence here. We have already noted that the Clean Air Act's provisions regarding oxygenate fuel additives "maintain[ ] state authority to adopt and enforce the strongest standards to prevent air pollution." *Exxon Mobil*, 217 F.3d at 1253. Those provisions also preserve state authority to adopt and enforce measures to prevent water pollution, even if those measures may, to some degree, disrupt the gasoline market and cause higher prices. California's MTBE ban thus does not "frustrate[ ] the full effectiveness of federal law." *Perez v. Campbell*, 402 U.S. 637, 652 (1971).

[8] For the foregoing reasons, we conclude that while California's ban on MTBE is not specifically exempted from preemption by the Clean Air Act, it is nonetheless not preempted, either expressly or impliedly, by the Act.

AFFIRMED.

Case No. 01-71356

IN THE UNITED STATES COURT OF APPEALS
FOR THE NINTH CIRCUIT

GRAY DAVIS, Governor of the STATE
OF CALIFORNIA, and the
CALIFORNIA AIR RESOURCES
BOARD,

Petitioners,

v.

UNITED STATES ENVIRONMENTAL
PROTECTION AGENCY, and
CHRISTINE TODD WHITMAN, its
Administrator,

Respondents.

On Petition for Review from the United States Environmental Protection Agency

AMICUS CURIAE BRIEF OF THE STATES OF CONNECTICUT, MAINE, MASSACHUSETTS, NEW HAMPSHIRE AND NEW YORK IN SUPPORT OF REVERSAL OF EPA'S DENIAL OF CALIFORNIA'S REQUEST FOR A WAIVER UNDER THE CLEAN AIR ACT

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IDENTITY AND AUTHORITY OF THE AMICI CURIAE

Amici, the States of Connecticut, Maine, Massachusetts, New Hampshire and New York (collectively, the "Northeast states"), file this brief pursuant to Fed. R. App. P. 29(a) in support of California's appeal following EPA's denial of its request for a waiver from the Clean Air Act's oxygen requirement for reformulated gasoline.

INTEREST OF THE AMICI CURIAE

The Northeast states suffer smog from excess ground-level ozone in the summer. To reduce emissions of pollutants that contribute to ozone, as well as toxic emissions, gasoline dealers in some Northeast states are required to sell federal reformulated gasoline ("RFG"). The RFG program generally produces lower emissions of chemicals that lead to the formation of ozone and lower emissions of toxic chemicals by controlling the composition of RFG. One of the many parameters is that RFG must contain at least two percent oxygen by weight. In the Northeast, refiners have met this requirement primarily by adding the oxygenate methyl tertiary butyl ether ("MTBE") to RFG.

The Northeast states, like California, face a dilemma posed by unforeseen consequences of the oxygen requirement and the chemical properties of MTBE: either they continue to use MTBE in RFG and risk widespread contamination of drinking water or they use ethanol in RFG and emit more ozone-creating pollutants than RFG without any added oxygenates. For states to ensure both clean water and clean air, the U.S. Environmental Protection Agency ("EPA") must waive the oxygen requirement, as contemplated by the Clean Air Act ("CAA"), and allow the use of RFG without additional oxygen (which can still achieve the clean air benefits of the RFG program). California has met the statutory criteria for waiver. Unfortunately, the EPA, in a case of first impression, applied an incorrect standard and a results-oriented analysis to California's waiver request. This precedent will interfere with the ability of the Northeast states to obtain waivers and to reduce emissions of ozone-causing chemicals.

FACTS

Ozone Threatens Public Health

Ozone is the prime ingredient of smog and adversely affects public health, especially the health of vulnerable groups such as children and the elderly. EPA, Ozone: Good Up High, Bad Nearby, EPA/451/k-97-002 (Oct. 1997) <http://www.epa.gov/oar/oaqps/gooduphigh/#affect>.

The CAA requires EPA to establish national air ambient quality standards ("NAAQS") for ozone and other harmful pollutants. 42 U.S.C. § 7409. The Northeast and California represent nearly half of the counties nationwide that are in nonattainment of the current one-hour ozone NAAQS. EPA, Classifications of Ozone Non-Attainment Areas, <http://www.epa.gov/oar/oaqps/greenbk/onc.html>. EPA has established a more stringent eight-hour ozone NAAQS, see 62 Fed. Reg. 38856 (July 18, 1997),[1] and it is expected that even more areas, including areas in the Northeast, will be in nonattainment of this new ozone standard.[2]

The failure by any state to attain the ozone or other NAAQS will trigger possible sanctions, including loss of highway monies and federal takeover of the air quality planning process in the state. See Virginia v. EPA, 108 F.3d 1397, 1406 (D.C. Cir. 1997).

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[1] The new ozone standard was recently upheld. American Trucking Ass'ns, Inc. v. EPA, 283 F.3d 355 (D.C. Cir. 2002).

[2] In addition, particulate matter is a significant air quality and public environmental health problem, causing a wide range of adverse human health and environmental effects from premature death to decreased visibility, and California and parts of the Northeast are in nonattainment of the particulate matter NAAQS. EPA, Particulate Matter Nonattainment State/Area/County, (Aug. 2, 2001) <http://www.epa.gov/oar/oaqps/greenbk/pncs.html>. EPA established an additional and more restrictive particulate matter NAAQS that regulates particulate matter with a diameter of 2.5 microns or less ("PM-2.5") compared to the current standard of 10 microns ("PM-10"). See 62 Fed. Reg. 38651 (July 18, 1997). It is expected that many more areas, including some urban areas in the Northeast, will be in nonattainment of the PM-2.5 NAAQS than are currently in non-attainment of the PM-10 NAAQS.

Reducing Emissions is Critical to Attaining Ozone NAAQS

Ozone is formed by a complex interaction of various chemicals. The main precursors to ozone formation are nitrogen oxides ("NOx") and volatile organic compounds ("VOCs"). EPA, Ozone: Good Up High, Bad Nearby, EPA/451/k-97-002 (Oct. 1997) <http://www.epa.gov/oar/oaqps/gooduphigh/#affect>; see generally 63 Fed. Reg. 57356, 57359 (Oct. 27, 1998) (discussing formation of ozone and its harmful effects); Virginia v. EPA, 108 F.3d at 1399-1400 (same). Until recently ozone control focused on reducing VOC emissions, but a National Academy of Sciences ("NAS") report commissioned by Congress, 42 U.S.C. § 7511f, found that "NOx control is necessary for effective reduction of ozone in many areas of the United States" and recommended that "the control of NOx emissions will probably be necessary in addition to, or instead of, the control of VOCs." NAS, Rethinking the Ozone Problem in Urban and Regional Air Pollution 11 (1991) <http://www.nap.edu/books/0309046319/html/index.html>. Other chemicals contribute to a lesser degree to ozone formation; it takes over 31 tons of carbon monoxide ("CO"), for example, to equal the ozone-forming potential of one ton of hydrocarbon [e.g., VOC] emissions. See Letter from emissions of VOCs and toxic air pollutants. 42 U.S.C. § 7545(k)(3)(B). Congress recognized the importance of NOx in the formation of ozone and mandated that the use of RFG must, at a minimum, not increase NOx emissions. See 42 U.S.C. § 7545(k)(2)(A). Indeed, advances in EPA's understanding of the role of NOx emissions have prompted the Agency to require a 6% decrease in NOx emissions for Phase II RFG. See 40 C.F.R. § 80.41(f).

Congress also required that RFG contain at least 2% oxygen by weight. 42 U.S.C. § 7545(k)(2)(B). This requirement was passed partly to promote more complete combustion and to reduce polluting emissions and partly to create an additional market for corn products such as ethanol. See Sen. Comm. on Env't and Pub. Works, I A Legislative History of the Clean Air Act Amendments of 1990 1267, 1303 (1993) (excerpts from Congressional debate). Yet Congress judged that the CAA's overriding goal of clean air must trump other, subordinate policies behind the oxygen mandate, and explicitly created mechanisms for EPA to waive the oxygen mandate if its continuation "would prevent or interfere with the attainment by the area of a national primary ambient air quality standard," 42 U.S.C. § 7545(k)(2)(B). See also 42 U.S.C. § 7545(k)(2)(A) (allowing waiver of oxygen requirement if it increases NOx emissions).

Areas in "severe" nonattainment of the ozone NAAQS are required to use RFG. See 42 U.S.C. § 7545(k)(10)(D). The designated metropolitan areas that must use RFG in the Northeast include the New York City metropolitan area (including northeast New Jersey and southwestern Connecticut), the greater Hartford area, and the Philadelphia consolidated metropolitan statistical area (including portions of New Jersey). EPA, List of Reformulated Gasoline Program Areas (Jan. 5, 2001) <http://www.epa.gov/otaq/rfgarea.html>. Other ozone nonattainment areas may voluntarily "opt in" to the RFG program to control ozone. 42 U.S.C. § 7545(k)(6). Such areas in the Northeast that have opted into the RFG program include portions of Connecticut, New Jersey, New York, New Hampshire, and Maine and the entire states of Massachusetts and Rhode Island. EPA, List of Reformulated Gasoline Program Areas (Jan. 5, 2001) <http://www.epa.gov/otaq/rfgarea.html>.

MTBE Has Been Used to Meet the Oxygen Requirement in the Northeast and California

Although neither the CAA nor EPA regulations require the use of any particular oxygenate to meet the minimum oxygen levels of the RFG program,[4] refiners commonly blend in either MTBE or ethanol to meet this requirement. In the Northeast, as in California, refiners have used MTBE almost exclusively to satisfy the oxygen requirement in RFG because it is relatively inexpensive, has clean-burning characteristics, provides a good source of octane and can be shipped through existing pipelines. See Northeast States for Coordinated Air Use Management ("NESCAUM"), RFG/MTBE Findings & Recommendations 11 (Aug. 1999) <http://www.nescaum.org/pdf/MTBE_PH2/Ph2summ.pdf> ("NESCAUM MTBE Report"). Approximately three-quarters of all gasoline sold

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[4] EPA merely certifies that gasoline with various concentrations of additives, including MTBE, is either "substantially similar" to certain baseline fuel or does not impair emission control devices. 42 U.S.C. §§ 7545(f)(1), (4); see 46 Fed. Reg. 38582 (July 28, 1981); 44 Fed. Reg. 12242 (Mar. 6, 1979). EPA's determination, while a necessary precondition to the use of certain gasoline, does not constitute authorization or approval of MTBE. Indeed, MTBE producers must provide a binding assurance to EPA that they will not in any manner "represent . . . that registration of the additive constitutes endorsement, certification, or approval by any agency of the United States." 40 C.F.R. § 79.21(g).

in the Northeast is RFG, requiring the use of over one billion gallons of MTBE in the region every year. Id.[5]

MTBE Contaminates Drinking Water

Over the past decade, public health authorities have realized that an unforeseen consequence of increased MTBE use in RFG is a parallel increase in MTBE contamination of groundwater. As the EPA noted, "existing information on contamination of drinking water resources by MTBE indicates substantial evidence of a significant risk to the nation's drinking water supply." Advance Notice of Intent To Initiate Rulemaking Under the Toxic Substances Control Act To Eliminate or Limit the Use of MTBE as a Fuel Additive in Gasoline, 65 Fed. Reg. 16094, 16095 (Mar. 24, 2000). About 9 million gallons of gasoline are leaked or spilled into the U.S. environment every year, id. at 16098, and a significant portion of this gasoline contains MTBE. Once spilled, MTBE moves rapidly through soil and contaminates groundwater because it is highly soluble and resistant to biodegradation, much more so than other hazardous gasoline components such as benzene, toluene, ethylbenzene and xylenes. Id. at 16097. For these reasons, a nationwide study by the U.S. Geological Survey ("USGS")

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5. Refiners also add much smaller quantities of MTBE and ethanol to conventional gasoline to boost octane and thereby reduce engine knock.

detected MTBE in 21% of ambient groundwater where MTBE is used in RFG, compared with 2% in areas using conventional gasoline. Id. at 16099.

This widespread MTBE contamination threatens public health because groundwater is used as drinking water by 40 to 46% of the U.S. population, and concentrations of MTBE as low as 2.5 parts per billion ("ppb") for odor and 2 ppb for taste in drinking water can render it unpotable with an unpleasant turpentine-like taste and odor. Id. at 16097.[6] In fact, drinking water supplies in the Northeast have already been affected by MTBE. A joint USGS/EPA study of 12 Northeastern states found that MTBE was detected in 7% of the region's drinking water supplies, and was detected five times more frequently in drinking water in areas where gasoline must contain oxygenates than in other areas. Id. at 16099. Another study by the Northeast states found MTBE at low levels in about 15% of the region's drinking water. NESCAUM MTBE Report, p. 14.[7]

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[6] MTBE may pose other health threats but the scientific evidence is not yet definitive. Id. at 16098. Nonetheless, Congress has listed MTBE as a hazardous air pollutant, 42 U.S.C. § 7412(b)(1), and the EPA has classified MTBE as a possible human carcinogen, 65 Fed. Reg. at 16098, has designated MTBE as a proposed mobile source toxic, 65 Fed. Reg. 48058, 48067 Table II-1 (Aug. 4, 2000), and has proposed listing MTBE as a contaminant "of special interest" under the Safe Drinking Water Act because of its potential for contaminating drinking water, 62 Fed. Reg. 52194, 52211 (Oct. 6, 1997).

[7] In addition, a 1998 Maine study found that MTBE was present in 15.8%
(continued...)

Although only a small percentage (.5 to 1.5%) of MTBE detections in the Northeast's drinking water to date are above current applicable standards,[8] the amici states are concerned about the serious potential for drinking water contamination because groundwater supplies in the Northeast are typically drawn from fractured bedrock aquifers or sand and gravel aquifers that are susceptible to groundwater contamination. NESCAUM MTBE Report, p. 17.

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7. (...continued)
of sampled household wells and 16% of public water systems. 65 Fed. Reg. at 16100. In New Hampshire, MTBE has been detected in 15.2% of active public water systems. A New York survey found MTBE in groundwater at 32% of 5,262 reported gasoline spills undergoing remediation and concluded that MTBE has already affected the water supply of at least 178,671 New Yorkers. New York State Department of Environmental Conservation ("DEC"), Survey of Active New York State Gasoline Remediation Sites with Potential MTBE Contamination, at p. 2, Table 4 (Feb. 8, 2000) <http://www.dec.state.ny.us/website/der/mtbesurv.pdf>.

[8] The EPA has issued a non-regulatory advisory that MTBE should be kept below 20 to 40 ppb, 65 Fed. Reg. at 16097, but the taste and odor problems and possible health concerns at lower concentrations have prompted states to impose more restrictive standards. For example, California established a secondary drinking water standard of 5 ppb and has proposed a primary health-based standard of 13 ppb, id. at 16097 and 16098, New Hampshire has proposed a primary health-based standard of 13 ppb, id. at 16098, and New York has reduced groundwater remediation guidance values for MTBE from 50 ppb to 10 ppb, and is similarly revising the drinking water standard, DEC, Technical & Operational Guidance Series 1.1.1, Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations Table 1 (Apr. 2000).

The Northeast States' Strategies to Limit MTBE and to Protect Their Drinking Water

EPA convened a Blue Ribbon Panel to evaluate the considerable evidence regarding water contamination from MTBE. The Panel concluded that "MTBE is detected ten times more often in drinking water from community water systems in areas that use [RFG] or [the related Oxyfuel program] than in non-RFG/[Oxyfuel] areas." EPA Blue Ribbon Panel, Achieving Clean Air and Clean Water: The Report of the Blue Ribbon Panel on Oxygenates in Gasoline (Sept. 15, 1999), Excerpts of Record Tab O, pp. 14-15. The Blue Ribbon Panel recommended that MTBE be phased out of RFG, id., pp. 13-21, 86, 88, by, among other things, the immediate removal of the RFG program's oxygen mandate, id., p. 87. EPA began to implement the Panel's recommendations by initiating a rulemaking under the Toxic Substances Control Act to limit or eliminate use of MTBE in gasoline. 65 Fed. Reg. 16094 (Mar. 24, 2000).

Unable to wait for federal action while their water supplies are threatened, a number of the Northeast states have followed California and taken action to reduce MTBE use. Connecticut and New York have banned MTBE by October 1, 2003 and January 1, 2004 respectively, and other states are considering similar steps. In addition, voluntary RFG areas in the Northeast may choose to opt out of the program entirely to avoid MTBE contamination: Maine opted out of the RFG program for this reason in 1999, and other voluntary RFG areas will likely opt out as soon as they are able. See 40 C.F.R. § 80.72 (opt-in states must remain in RFG program until 2004). Indeed, New Hampshire has petitioned EPA for permission to opt out of the federal RFG program, and has further requested permission to opt out before 2004.

The Oxygen Requirement is Not Necessary to Have Cleaner-Burning RFG

Upon eliminating MTBE, the Northeast states, like California, face a de facto requirement to use ethanol in RFG because it is the only other oxygenate available in sufficient quantities. But California's study of fuels has established that RFG with ethanol will increase NOx emissions compared to RFG with MTBE, which pollutes water, or compared to new RFG that would not need to use any oxygenates to meet the other statutory requirements of the RFG program, such as caps on emissions of NOx, VOCs and toxic air pollutants and limits on the allowable concentrations of benzene, aromatic hydrocarbons and heavy metals in RFG. See 42 U.S.C. §§ 7545(k)(2), (3). Based on its evidence that RFG containing ethanol will worsen air emissions, California sought a waiver of the oxygen requirement from EPA and, when EPA denied the waiver, appealed directly to this Court.

The Northeast states have analyzed RFG with ethanol and agree with California – the large-scale use of ethanol is likely to increase ozone.[9] Specifically, gasoline with ethanol blended at high volumes produces both greater tailpipe emissions of NOx and greater evaporative emissions of VOCs and other toxics due to (1) the relatively high volatility of ethanol-blended fuel, (2) commingling of ethanol and non-ethanol blends in vehicle fuel tanks, (3) increased fuel permeation through fuel lines and hoses, (4) reduced effectiveness of on-board vapor recovery systems and (5) increased truck and barge traffic to transport ethanol to and within the region. NESCAUM, II <u>Health, Environmental and Economic Impacts of Adding Ethanol to Gasoline in the Northeastern States</u> 10-16 (2001) <http://www.nescaum.org/committees/ethanol-report.html>.

Alternatively, it is technically feasible to produce RFG without oxygenate additives that achieves air quality benefits, including lower NOx emissions, equivalent to or greater than those produced by RFG with oxygen from the addition of MTBE or ethanol.[10] California's Phase 3 Cleaner-Burning Gasoline,

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[9] Such fuel is also likely to increase particulate matter emissions.

[10] Potential non-oxygenate alternatives to MTBE include alkylates and iso-octane, which provide octane without apparent toxic emissions increases. As (continued...)

for example, does not contain oxygenates and is cleaner burning than RFG with added oxygenates. And New Hampshire has filed a petition with EPA to opt out of the RFG program and to substitute its own fuel program, which will not require a minimum oxygen content.

The amici have a specific interest in avoiding the Hobson's choice between more polluted air (attributable to ethanol use) and more polluted water (attributable to MTBE use). In order to attain current NAAQS, let alone comply with EPA's more stringent planned NAAQS for ozone, the Northeast states will be required to maximize both NOx and VOC reductions from mobile sources through the RFG program in order to make the necessary deep cuts in emissions of ozone precursor chemicals. Because ethanol-containing RFG will jeopardize these plans, New York and Connecticut are preparing waiver requests, and other Northeast states may also file waiver requests.

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10. (...continued)
long as the oxygen mandate is in effect, however, refiners are unlikely to assess the full environmental and public health impacts of non-oxygenate replacements to avoid the unanticipated effects that have plagued MTBE or to invest in production capabilities to make sufficient quantities of these oxygenate alternatives.

ARGUMENT

I. EPA APPLIED SPECULATIVE ANALYSIS AND AN INCORRECT STANDARD TO CALIFORNIA'S WAIVER REQUEST

A court may set aside an EPA decision as arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with the law where, for example, the Agency has "relied on factors which Congress has not intended it to consider, entirely failed to consider an important aspect of the problem, [or] offered an explanation for its decision that runs counter to the evidence before the agency . . . ." Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 43 (1983).[11] In denying California's request for a waiver of the oxygen mandate, EPA made three errors. First, EPA used a flawed analysis of a waiver's impact on the ozone NAAQS and improperly discounted California's evidence that a waiver would result in lower NOx emissions. Second, EPA

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[11] It is unclear whether the standard of review in 42 U.S.C. § 7607(d)(9) applies to EPA's non-rulemaking action at issue in this case because there is no indication that Agency made a determination that the subsection applies in accordance with 42 U.S.C. § 7607(d)(1)(V), but the Agency did establish a docket in accordance with 42 U.S.C. § 7607(d)(2). It makes little difference, however, because the CAA arbitrary and capricious standard is the same as the analogous standard under the Administrative Procedure Act ("APA"), 5 U.S.C. § 706(2). Western States Petroleum Ass'n v. EPA, 87 F.3d 280, 283 (9th Cir. 1996); see also Allied Local and Regional Mfrs. Caucus v. EPA, 215 F.3d 61, 68 (D.C. Cir. 2000) (APA and CAA standards are the same and State Farm used for guidance in a CAA case).

compounded this error by requiring California to "clearly demonstrate" that a waiver would improve NAAQS attainment, rather than apply the less stringent CAA standard, which simply requires a showing that the oxygen requirement "interferes with" attainment of a NAAQS. Third, EPA ignored the general CAA command to consider the effect of the oxygen requirement for each applicable NAAQS independently, instead requiring California to show that all applicable NAAQS would be interfered with and ignoring California's argument and evidence that the oxygen requirement would interfere with the particulate matter (PM-10) NAAQS. For these reasons, EPA's decision was arbitrary and capricious.[12]

A. EPA's Disregard of NOx and Reliance on Inconclusive Predictions for VOC Emissions Was Arbitrary and Capricious

California met the statutory criteria for waiver by demonstrating that the oxygen standard would interfere with attainment of the ozone NAAQS. Amici agree with California's demonstrations and rely on their arguments to that effect, but make this separate submission to emphasize that EPA's denial was

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[12] While amici address EPA's stated reasons for denial in this brief, it has been reported that EPA denied California's waiver request and forced the use of ethanol only after the Administration was heavily lobbied by lawmakers, governors and agricultural trade groups who support the creation of ethanol markets and the resulting higher prices for corn. See Support Grows for Corn-Based Fuel Despite Critics, New York Times, July 23, 2001, p. A1.

substantively flawed because the Agency ignored the importance of NOx emissions.

In order to attain the ozone NAAQS, California must obtain NOx emission reductions from every available source. California's petition therefore emphasized that additional NOx reductions from mobile sources were needed beyond those commitments in its recently approved SIP, that a waiver would allow California to achieve those reductions, and conversely that rejection of a waiver and the resulting use of ethanol-RFG would increase NOx emissions and interfere with attainment of the ozone NAAQS. EPA agreed with California's prediction for NOx emissions, stating that its own analysis "shows a likely decrease of NOx under all scenarios [with a waiver] examined . . . ." Analysis of and Action on California's Request for a Waiver of the Oxygen Content in Gasoline (June 2001), Excerpt of Record Tab K ("Analysis"), p. 8.[13] Since NOx is one of the two important precursors causing ozone, and maximizing NOx reductions is crucial to controlling ozone, California met the statutory test for waiver by demonstrating that the oxygen requirement would interfere with attainment of the ozone NAAQS.

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[13] Although EPA states that its finding that a waiver would reduce NOx emissions "is unique to California's regulatory structure and specific to California refineries' technical configurations," id., the Northeast states will also be able to show that waivers will reduce NOx emissions.

In the face of unequivocal evidence that NOx emissions will increase with the use of ethanol, however, EPA denied California's waiver request because the Agency predicted that a waiver would increase CO emissions and, more importantly, might either increase or decrease VOC emissions. Analysis, pp. 9-12. EPA's analysis – which improperly looked beyond whether the oxygen requirement "interferes with" NAAQS attainment – is flawed for two additional, substantive reasons.

First, EPA overestimated the impact of CO on ozone formation. Although NOx, VOCs and CO all contribute to ozone formation, NOx and VOCs each have a much greater effect on the formation of ozone than the equivalent amount of CO. See Letter from California Air Resources Board to EPA (Sept. 20, 1999), Excerpt of Record Tab E, p. 4 (one ton of hydrocarbons makes the same contribution, on average, as 31 tons of CO). EPA considered the relative contributions that VOCs and CO make to ozone formation, see Technical Support Document: Analysis of California's Request for Waiver of the Reformulated Gasoline Oxygen Content Requirement for California Covered Areas, Excerpt of Record Tab L ("Technical Support Document"), p. 126, n.88, and concluded that the relative reactivity factors meant that VOC decreases alone would completely or partially offset any CO increases in ten out of twelve predicted scenarios. But EPA did not then consider the relative importance of NOx compared to CO in ozone formation. Given the unquestioned reductions in NOx emissions with a waiver, and the much greater importance of NOx to ozone formation compared to CO, any CO increases not already offset by VOC reductions would have been offset by the NOx emission reductions. It was arbitrary for EPA to ignore this effect.

Second, EPA improperly used uncertain VOC predictions to negate the unequivocal reduction in NOx emissions that would result from a waiver. EPA's predictions regarding VOC emissions were, in its own words, "mixed": with a waiver, exhaust VOC emissions would increase but evaporative emissions and permeation emissions (from fuel escaping through fuel system components) would decrease. In fact, in balancing these effects, EPA concluded that "the net result of these opposite exhaust and non-exhaust effects would be a <u>reduction</u> in VOC emissions with a waiver, though the magnitude of the reduction varies across scenarios [using RFG]." <u>Analysis</u>, p. 9 (emphasis added).[14]

After reaching this conclusion, however, EPA speculated that the commingling of ethanol-oxygenated RFG with non-ethanol gasoline in the

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[14] The Northeast states also believe that EPA greatly underestimated the increase in permeation emissions from ethanol-oxygenated RFG and the increase in indirect emissions from the transport of ethanol by diesel trucks and barges from the Midwest.

gasoline tanks of California cars might increase net VOC emissions. Analysis, pp. 9-12.[15] It is undisputed that a mixture of ethanol-oxygenated gasoline and non-oxygenated gasoline will have a higher volatility than either of the two gasolines alone, and that this commingling effect will increase VOC emissions to some extent. Where MTBE is banned, more ethanol will likely be used to boost octane in both RFG and conventional gasoline markets and to meet the oxygenate mandate in RFG markets, thereby increasing the likelihood of commingling because some people will fill up their cars with gasoline in different areas. But as EPA conceded, the "magnitude [of the commingling effect] is very difficult to forecast as it depends upon estimates of the oxygenated/non-oxygenated market share, the oxygen content used in ethanol-oxygenated RFG, and vehicle owners' refueling behavior (including brand loyalty and full versus partial fill-ups), among other variables," and the variables "have been only crudely estimated." Analysis, pp. 10, 12.

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[15] Federal and state regulations prohibit commingling in the fuel distribution system and any commingling will principally occur through the behavior of consumers, who are not regulated in this respect. However, dealers may buy gasoline from low bidders without regard to commingling restrictions, and compliance surveys of gas stations have found samples with significant amounts of both ethanol and MTBE.

In addition to relying on "crude estimates" of commingling for its net VOC increase speculation, EPA did not even suggest that a waiver would affect that ultimate net result. Even without a waiver, the extent to which drivers will fill up with both RFG and regular gasoline is a crucial assumption. For example, Californians who work in the greater Los Angeles and Sacramento RFG areas and live outside those areas might be expected to fill up their cars with non-oxygenated gasoline where they live and ethanol-oxygenated RFG where they work, which would create a significant cross-border commingling effect in the absence of a waiver. Indeed, these commuters might be expected to drive long distances every day and thus compound the commingling effect. But EPA ignored the difference in the magnitude of cross-border commingling with and without a waiver. Id., n.8. This omission allowed EPA to predict that "there would be no appreciable commingling effects" without a waiver because all of the gasoline in RFG areas would contain ethanol. Id., p. 10. EPA's flawed baseline in turn made it easier for the Agency to conclude that a waiver would increase the commingling effect.

EPA's commingling errors would be even more arbitrary if applied by the Agency to deny oxygen waiver petitions from Northeast states. The gasoline market in the Northeast consists of many political and air quality jurisdictions, including RFG areas where oxygenates are required and conventional gasoline areas where oxygenates are not required. Northeast commuters travel across separate fuel areas on a daily basis, the main travel corridors such as Interstate 95 cut across different fuel areas, and different state and county gasoline taxes likely induce strategic filling behavior by drivers. The Northeast distribution system may also induce "spillover," the phenomenon where RFG is sold in non-RFG areas as conventional gasoline simply because it is cheaper to sell one gasoline than to establish separate distribution systems. Accordingly, amici expect that if EPA were to deny waiver petitions from Northeast states, ethanol-oxygenated RFG in the Northeast would create a greater commingling effect than in California and, conversely, that waivers would not appreciably increase the commingling effect in the Northeast. EPA's failure to consider cross-border effects in the Northeast would therefore artificially inflate the likelihood of an increase in VOC emissions with a waiver and underestimate the important benefits of NOx reductions.

EPA acknowledged that "the impact of a waiver on VOC emissions is considerably more complex to model" than the impact on NOx and CO emissions. Analysis, p. 12. The vulnerability of commingling predictions to different assumptions means that this Court must carefully scrutinize EPA's methods for results-oriented analysis and should demand that EPA use a more rigorous analysis. On the record before it, this Court should determine that EPA's reliance on commingling and "crudely estimated" assumptions was arbitrary and capricious.

B. EPA's "Clearly Demonstrated" Standard is Contrary to the CAA

EPA compounded its substantive errors by applying an incorrect legal standard. Under the CAA, waiver is warranted when the oxygen requirement "would prevent or interfere with the attainment by the area of a national primary ambient air quality standard." 42 U.S.C. § 7545(k)(2)(B) (emphasis added). In its preliminary analysis, EPA admitted that "interfere with" is a relatively low evidentiary threshold satisfied by "an effect that makes achieving the NAAQS more difficult, but that does not itself necessarily prevent attainment." Technical Support Document, p. 131.[16]

In its final analysis, however, EPA explained that interference could only be shown if "the impacts of a waiver are clearly demonstrated for each applicable NAAQS." EPA, Analysis, p. 3 (emphasis added). EPA further required California

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[16] For example, delay in attaining a NAAQS would be interference even if attainment is not ultimately prevented. That is consistent with EPA's assessment of whether proposed SIP revisions will not delay attainment and thus meet the necessary non-interference showing. See Hall v. EPA, 273 F.3d 1146, 1158 (9th Cir. 2001).

to make "a clear demonstration that the changes in emissions resulting from a waiver would have a beneficial impact for purposes of attaining one NAAQS, and would not hinder attainment for any other NAAQS." Technical Support Document, p. 145 (emphasis added).

The burden of proof required by EPA is not a reasonable interpretation of the CAA's "interfere with" standard and therefore is due no deference by this Court. See Chevron USA, Inc. v. Natural Resources Defense Council, Inc., 467 U.S. 837 (1984).[17] EPA required California to meet a "clear demonstration" burden of proof and effectively required California to prove that there were no uncertainties about whether a waiver would produce air benefits, not that the oxygen requirement interfered with air quality. EPA's "clear demonstration" test was akin to the "clear and convincing" evidence standard reserved for special circumstances, if not akin to the "beyond a reasonable doubt" test reserved for criminal matters.

Given that the CAA waiver provision is silent as to the burden of proof, standard rules of construction dictate that California only need show interference

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[17] Amici would not take issue with EPA's restatement of the standard as requiring a "beneficial impact" if that were taken as merely the converse of demonstrating no interference. But the burden of proof required by EPA makes clear that "beneficial impact" is different than the "interferes with" standard.

by a preponderance of the evidence. See Bender v. Clark, 744 F.2d 1424, 1429-30 (10th Cir. 1984) (rejecting agency's use of "clear and definite" standard to determine bid for mineral lease that did not involve particularly important individual rights, and imposing preponderance of the evidence standard even though agency action was not governed by 5 U.S.C. § 556(d)). See generally Richard J. Pierce, II Administrative Law Treatise § 10.7 at 763-66 (4th ed. 2002). Accordingly, EPA's "clear demonstration" standard was an improper application of the CAA's waiver provision.[18] Indeed, EPA's stringent standard undermines the waiver mechanism Congress intended to protect states from the unintended consequences of the oxygen mandate.

Not only did the high evidentiary burden created by EPA preordain that California's waiver request would be denied, but it is inconsistent with the longstanding deference that Congress and EPA have given to California's air pollution control programs, especially with regard to motor vehicles and fuels. See 42 U.S.C. § 7543(b) (no preemption of California vehicle emission controls); 42 U.S.C. § 7545(c)(4)(B) (no preemption of California requirements for fuels and

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[18] As EPA admits, its interpretation thereby raised the level of proof for interference to at least that required for a SIP state fuel control that must be "necessary to achieve" a NAAQS under 42 U.S.C. § 7545(c)(4)(C). Technical Support Document, p. 145.

fuel additives). California has the most effective mobile-source emission control program in the world, and California's technical analysis is viewed with great deference by other states and by affected industries.

C. EPA's Failed to Consider Interference with Attainment of the Particulate Matter NAAQS

EPA also acted arbitrarily by declining to reach California's argument that the oxygen requirement would interfere with the PM-10 NAAQS. See Analysis, p. 14, n.15. The CAA clearly provides that waiver is warranted when the oxygen requirement "would prevent or interfere with the attainment by the area of a national primary ambient air quality standard." 42 U.S.C. § 7454(k)(2)(B) (emphasis added). Rather than perform a separate, independent analysis for both the ozone and PM-10 NAAQS, however, EPA stated that it "should not grant a waiver unless the impacts of a waiver are clearly demonstrated for each applicable NAAQS." Analysis, p. 3 (emphasis added). EPA's standard meant that the Agency had to accept California's proof of interference with all applicable NAAQS. Thus, when EPA rejected California's ozone showing, it declined to reach California's alternative PM-10 showing. See Analysis, p. 14, n.15. EPA's omission violated the CAA's command to analyze each affected NAAQS.

Had EPA considered the merits of the alternative particulate matter argument, California would have met the statutory test for waiver. The Agency has not challenged California's evidence that NOx emissions will be higher without a waiver than with a waiver and has long acknowledged that NOx contributes to the formation of particulate matter. E.g., EPA, Nitrogen Oxides: Impact on Public Health and the Environment 52-64 (1997). Indeed, NOx is the single most important precursor to particulate matter formation in California, and increased NOx emissions will interfere with California's attainment of the PM-10 NAAQS. Even under EPA's more stringent and thus incorrect "clear demonstration" test, California would have prevailed because it had shown "that the changes in [NOx] emissions resulting from a waiver would have a beneficial impact for purposes of attaining . . . [the PM-10] NAAQS, and would not hinder attainment for any other [e.g., ozone] NAAQS." See Technical Support Document, p. 145.

EPA's failure to consider whether the oxygen mandate interferes with attainment of the PM-10 NAAQS is even more egregious because recent EPA studies show that exposure to fine particulate matter, due largely to emissions of NOx and sulfur dioxide from combustion sources like motor vehicles and power plants, causes increased mortality and chronic respiratory illness at a great cost to

II. EPA'S DENIAL WILL FORCE STATES TO CHOOSE BETWEEN CLEAN WATER AND CLEAN AIR AND WILL PRECLUDE REGIONAL SOLUTIONS

EPA's errors in denying California's waiver request – the first submitted under the CAA – have national effects.

Without the ability to obtain a waiver, states that now use RFG will have the unfortunate choice between allowing their drinking water supplies to be threatened by MTBE and using ethanol and suffering worse air pollution. Widespread MTBE contamination in the Northeast, for example, has caused states to ban or strictly limit MTBE to protect drinking water. And the use of ethanol, the only oxygenate currently available in quantities that are potentially sufficient to meet the RFG program's oxygen requirement, will worsen air quality compared to RFG that is designed to be clean burning without the addition of oxygen. Yet EPA's arbitrary standard for granting a waiver makes it more difficult for Northeast states to obtain waivers and thereby jeopardizes their efforts to attain the ozone and particulate matter NAAQS.

In addition, the oxygen requirement precludes effective regional solutions for reducing ozone pollution, one of the major goals of the CAA. E.g., 42 U.S.C. § 7406 (encouraging formation of interstate air quality agencies), 42 U.S.C. § 7426 (establishing procedures for states to abate interstate pollution), 42 U.S.C.

§ 7506a (authorizing interstate transport commissions). The CAA specifically requires the Northeast states to work together on the ozone nonattainment problem. 42 U.S.C. § 7511c (establishing Northeast ozone transport commission). The Northeast states already cooperate extensively on air quality issues and are well suited to developing a regional market for RFG without oxygen that can be tailored to the regional airsheds and ozone problem. But unless the EPA grants waivers, the mandatory RFG areas in the Northeast – greater New York, Hartford and Philadelphia – will not be able to participate in a regional market for such fuels. EPA's denial of waivers would instead fragment the Northeast gasoline markets between mandatory RFG areas and voluntary RFG areas that will likely opt out and use fuels that do not contain added oxygen.

Finally, the Northeast states must maximize NOx reductions from mobile sources because they are already pursuing other efforts to obtain NOx reductions from stationary sources in their jurisdiction and in upwind states. EPA should not preclude maximum NOx reductions by forcing states to use gasoline with an ethanol additive.

CONCLUSION

States are legally obligated both to achieve compliance with the ozone and particulate matter NAAQS and to protect public health and natural resources from MTBE contamination. These goals cannot be achieved without relief from the oxygen mandate, but EPA's denial of the California oxygen waiver request sets an unreasonably high standard that goes far beyond the CAA and relies upon arbitrary assumptions.

Dated: New York, New York
June 27, 2002

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CERTIFICATE OF COMPLIANCE

Pursuant to Rule 32(a)(7)(C) of the Federal Rules of Appellate Procedure and Ninth Circuit Rule 32-1, I certify that the Amicus Curiae Brief of the States of Connecticut, Maine, Massachusetts, New Hampshire and New York in Support of Reversal of EPA's Denial of California's Request for a Waiver under the Clean Air Act uses a proportionally spaced, 14-point font and, based on the word-counting function of the WordPerfect word-processing software system (located at file|properties|information), contains 6996 words.

Carter H. Strickland Jr.
CARTER H. STRICKLAND, JR.

CERTIFICATE OF SERVICE

I certify, pursuant to FRAP Rules 25(a)(2)(B) and 25(d) and Circuit Rule 31-1, that on June 27, 2002, I filed the Amicus Curiae Brief of the States of Connecticut, Maine, Massachusetts, New Hampshire and New York in Support of Reversal of EPA's Denial of California's Request for a Waiver under the Clean Air Act with the United States Court of Appeals for the Ninth Circuit by sealing an original and 15 copies in an enclosed envelope addressed to the Clerk of the Court, United States Court of Appeals for the Ninth Circuit, 95 Seventh Street, P.O. Box 193939, San Francisco, California 94119-3939, and causing such envelope to be placed in the collection system of an overnight courier for delivery the following day.

I further certify, pursuant to FRAP 25(d), that on June 27, 2002, I served the Amicus Curiae Brief of the States of Connecticut, Maine, Massachusetts, New Hampshire and New York in Support of Reversal of EPA's Denial of California's Request for a Waiver under the Clean Air Act upon each of the parties on the attached service list, at the address therein, by sealing two copies in an enclosed envelope, First Class postage pre-paid, and causing such envelope to be placed in the internal mail collection system of the Office of the New York State Attorney General, for deposit that same day with the United States Postal Service in accordance with the ordinary business practices of our office.

Carter H. Strickland, Jr.
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APPENDIX

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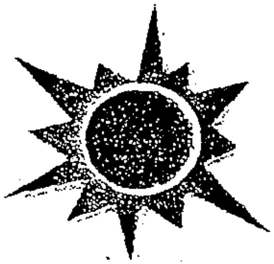
EPA 452/R-97-002
August 1997

Air

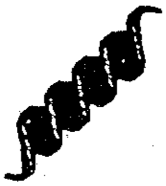
EPA

Nitrogen Oxides: Impacts on Public Health and the Environment

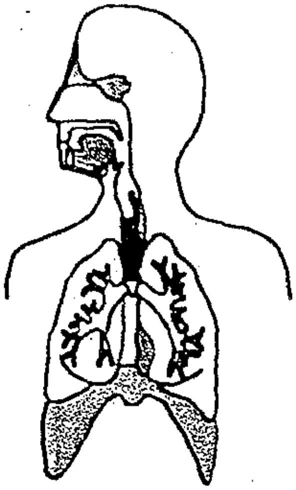


Stratospheric Ozone Depletion

Global Warming



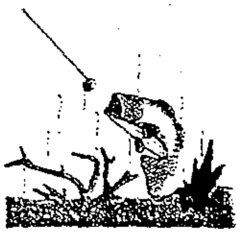
Toxic Products



Ozone, Particulate Matter, and Nitrogen Dioxide

Acid Deposition

Visibility, Drinking Water and Ecosystem Protection



Eutrophication

D. Particulate Matter

1. Goals of the Program

The EPA has established health and welfare standards for particulate matter (PM). The goals of the program are to achieve and maintain these clean air standards throughout the country. As described below, emissions of NO_x can result in the formation of particulate nitrates that can contribute to PM nonattainment in some areas. Decreases in NO_x emissions might be needed in some areas to attain the PM NAAQS. In other areas, NO_x emissions reductions may not be needed to attain the PM NAAQS, but could help maintain PM levels below the standard in attainment areas.

2. Status of the Programs

The NAAQS

Section 109 of the CAA directs the EPA Administrator to propose and promulgate primary and secondary NAAQS for pollutants identified under section 108. Section 109 defines a primary standard as that necessary to protect the public health, allowing an adequate margin of safety. A secondary standard, as defined in section 109, must specify an air quality concentration needed to protect the public welfare from any known or anticipated adverse effects associated with the presence of the pollutant in the ambient air. Welfare effects, as defined in section 302(h) of the CAA include, but are not limited to, effects on soils, water, crops, vegetation, materials, animals, wildlife, weather, visibility and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being.

States are primarily responsible for ensuring attainment and maintenance of the NAAQS. Under title I of the CAA, States are to submit, for EPA approval, SIPs that provide for the attainment and maintenance of such standards through control programs directed to sources of the pollutants involved. In addition, Federal programs provide for nationwide reductions in emissions of air pollutants through, for example, the New Source Performance Standards program under title I of the Act, which involves controls for major stationary sources.

PM

The term PM refers to a solid or liquid material that is suspended in the atmosphere. PM includes materials of both organic and inorganic composition, and generally can also be divided into a primary component and secondary component. Primary PM consists of solid particles, aerosols, and fumes emitted directly as particles or droplets from various sources. Secondary PM is produced from gaseous pollutants, mainly SO_2, NO_x, ammonia, and some VOCs. These precursor gases react with one another and with oxygen and water in the atmosphere to form particles or condensible compounds. The chemical and physical properties of PM vary greatly with time, region, meteorology, and source category, thus complicating their understanding and control.

The PM NAAQS

The PM NAAQS include $PM_{2.5}$ standards and PM_{10} standards. The $PM_{2.5}$ standards are set at 15 micrograms per cubic meter, annual mean, and 65 micrograms per cubic meter, 24-hour average. The PM_{10} standards are set at 50 micrograms per cubic meter, annual average, and 150 micrograms per cubic meter, 24-hour average. (For more details see the "Most Recent Review of the Particulate Matter NAAQS" section below).

Areas That Do Not Meet the PM_{10} NAAQS

In 1990 EPA designated 70 areas as moderate nonattainment for PM_{10}, and 13 additional areas were added in 1994 for a total of 83 PM_{10} nonattainment areas. Five of the initial areas have been reclassified to serious nonattainment areas. Based on air quality data for 1992 to 1994, 37 of these (but none of the serious areas) were determined to have met the PM_{10} NAAQS by their December 31, 1994 attainment date. The current 46 nonattainment areas are shown in Figure II-3 below.

AREAS DESIGNATED NONATTAINMENT FOR PM10 PARTICULATES

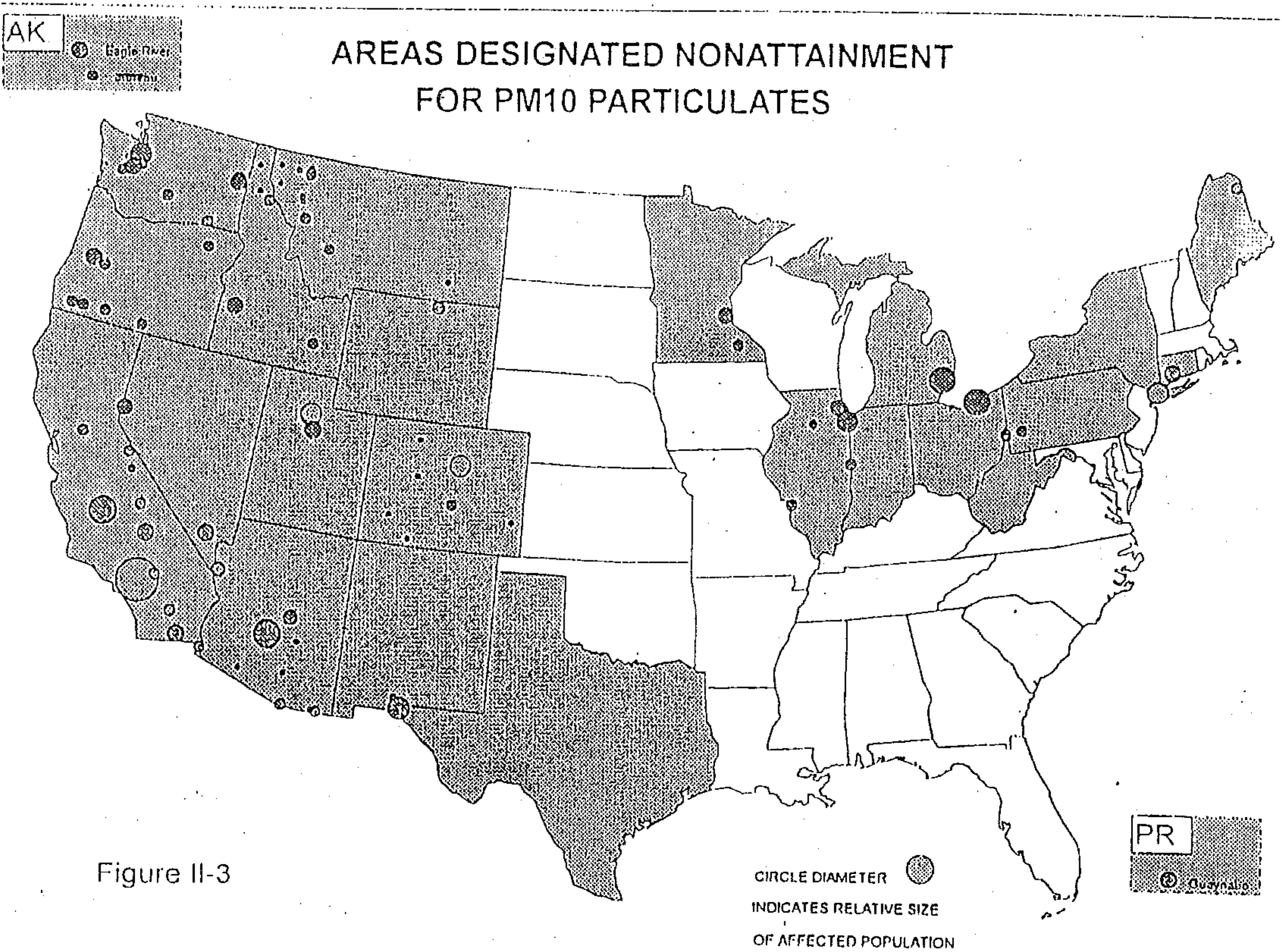


Figure II-3

OAQPS, AQSSD
FEBUARY, 20, 1998

Establishment of the PM NAAQS and Subsequent Reviews

Establishment of the NAAQS for PM

NAAQS for PM were first established in 1971 (April 30, 1971 Federal Register). The reference method specified for determining attainment of the original standards was the high-volume sampler, which collects PM up to a nominal size of 25 to 45 microns (so-called total suspended particulate or TSP). The primary standards (measured by the indicator TSP) were 260 micrograms per cubic meter, 24-hour average, not to be exceeded more than once per year, and 75 micrograms per cubic meter, annual geometric mean. The secondary standard (measured as TSP) was 150 micrograms per cubic meter, 24-hour average not to be exceeded more than once per year.

First Review of NAAQS for PM

In October 1979 (44 FR 56731), EPA announced the first review of the criteria document and NAAQS for PM and, after a lengthy and elaborate process, promulgated significant revisions of the original standards in 1987 (52 FR 24854, July 1, 1987). In that decision, EPA changed the indicator for particles from TSP to PM_{10}, the latter referring to particles with a mean aerodynamic diameter less than or equal to 10 microns.[9] EPA also revised the acceptable concentration and form of the primary standards by 1) replacing the 24-hour TSP standard with a 24-hour PM_{10} standard of 150 micrograms per cubic meter with no more than one expected exceedance per year averaged over 3 years and 2) replacing the annual TSP standard with a PM_{10} standard of 50 micrograms per cubic meter, expected annual arithmetic mean. The secondary standard was revised by replacing it with 24-hour and annual standards identical in all respects to the primary standards. The revisions also included a new reference method for the measurement of PM_{10} in the ambient air and rules for determining attainment of the new standards.

Most Recent Review of the PM NAAQS

To initiate its most recent review, EPA analyzed thousands of peer-reviewed scientific studies. These studies were then synthesized, along with a recommendation on whether the existing standards were adequately protective, and presented to an independent scientific advisory body ("CASAC"), as required by the CAA. After holding more than 125 hours of public discussion, and based upon 250 of the most relevant studies, CASAC concluded that EPA's current O_3 and particulate standards should be strengthened. This review took several years to complete.

On December 13, 1996, EPA proposed in the Federal Register to change the PM standard (61 FR 65638). As described in detail in that notice, EPA proposed to change the

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[9] The more precise term is 50 percent cut point or 50 percent diameter. This is the aerodynamic particle diameter for which the efficiency of particle collection is 50 percent. Larger particles are not excluded altogether, but are collected with substantially decreasing efficiency and smaller particles are collected with increasing (up to 100 percent) efficiency. Ambient samplers with this cut point provide a reliable estimate of the total mass of suspended particulate matter of aerodynamic size less than or equal to 10 microns.

current standards by adding two new primary $PM_{2.5}$ standards set at 15 micrograms per cubic meter, annual mean, and 50 micrograms per cubic meter, 24-hour average. The revisions would provide increased protection against a wide range of potential PM-related health effects. The proposed annual $PM_{2.5}$ standard would be based on the 3-year average of the annual arithmetic mean $PM_{2.5}$ concentrations, spatially averaged across an area. The proposed 24-hour $PM_{2.5}$ standard would be based on the 3-year average of the 98th percentile of 24-hour $PM_{2.5}$ concentrations at each monitor within an area. The EPA proposed to revise the current 24-hour PM_{10} standard of 150 micrograms per cubic meter by replacing the 1-expected-exceedance form with a 98th percentile form, averaged over 3 years at each monitor within an area. The EPA proposed to retain the current annual primary PM_{10} standard of 50 micrograms per cubic meter. In addition, EPA proposed to revise the current secondary standards by making them identical to the suite of proposed primary standards.

EPA then conducted an extensive public comment process, receiving approximately 57,000 comments at public hearings held across the country and through written, telephone and computer messages. The proposed standards were also subjected to an intensive inter-agency review process. A court order required EPA to finalize a PM standard by mid-July of this year, and EPA committed to a court to do the same for O_3.

EPA's final air quality standards for O_3 and PM were published in the Federal Register of July 18, 1997 (62 FR 38856). With respect to PM, the final standards include one significant change from EPA's 1996 proposal: the final standard set the 24-hour limit at 65 micrograms per cubic meter, instead of 50 micrograms (as proposed), to provide maximum flexibility for local areas and sources, while still retaining the public health protections of the proposal that are incorporated into the annual standard.

3. Science of NO_x and PM

Health and Welfare Effects

Exposure to airborne PM has a wide range of adverse health effects. The damages caused by PM vary depending on its concentration, composition, and the sizes of the constituent particles. A summary of these effects is provided below; for further information, see EPA's notice of proposed rulemaking on "National Ambient Air Quality Standards for Ozone and Particulate Matter" published in the December 13, 1997 Federal Register and relevant documents referenced in that notice.

As discussed in EPA's Criteria Document (EPA, April 1996) and Staff Paper (EPA, July 1996) and summarized in the December 13, 1996 proposal notice, the key health effects associated with PM include: 1) premature mortality; 2) aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days); 3) changes in lung function and increased respiratory symptoms; 4) changes to lung tissues and structure; and 5) altered respiratory defense mechanisms. Most of these effects have been consistently associated with ambient PM concentrations, which have been used as a measure of population exposure, in a number of community epidemiological studies. Although mechanisms by which particles cause effects have not been elucidated, there is general agreement that the cardio-respiratory system is the major target of PM effects.

The EPA revised the secondary (welfare-based) PM NAAQS by making them identical to the primary standards. The EPA believes that the $PM_{2.5}$ and PM_{10} standards, combined with the CAA required regional haze program, will provide protection against the major PM-related welfare effects. These welfare effects include visibility impairment, soiling, and materials damage. The Administrator of EPA signed the proposed rulemaking notice for the regional haze rules on July 18, 1997.

Size of Particles

The health and environmental effects of PM are strongly related to the size of the particles (EPA Staff Paper, 1996). The aerodynamic size and associated composition of particles determines their behavior in the respiratory system (i.e., how far the particles are able to penetrate, where particles are deposited, and how effective the body's clearance mechanisms are in removing them). Furthermore, particle size is one of the most important parameters in determining atmospheric lifetime of particles, which is a key consideration in assessing health effects information because of its relationship to exposure. The total surface area and number of particles, chemical composition, water solubility, formation process, and emission sources all vary with particle size. Particle size is also a determinant of visibility impairment, a welfare consideration linked to fine particle concentrations. Thus, size is an important parameter in characterizing PM, and particle diameter has been used to define the present standards.

Atmospheric Behavior of Fine and Coarse Particles

Sulfates, nitrates, and some organic particles as well as their precursors can remain in the atmosphere for several days and can be carried hundreds or even thousands of kilometers from their sources to remote locations such as national parks and wilderness areas (NRC, 1993). Fine particles are small enough that gravitational forces are largely overcome by the random forces from collisions with gas molecules. Thus fine particles tend to follow air streams and are difficult to remove by impaction on surfaces. Therefore, fine particles have very long lifetimes in the atmosphere, travel long distances, and tend to be more uniformly distributed over larger geographic areas than coarse particles (EPA, 1996). The atmospheric lifetimes of fine particles with respect to dry deposition is on the order of weeks. Removal of fine particles occurs when the particles absorb water, grow into cloud droplets, grow further to rain drops, and fall out as rain. This process lowers the atmospheric lifetime of fine particles to on the order of several days.

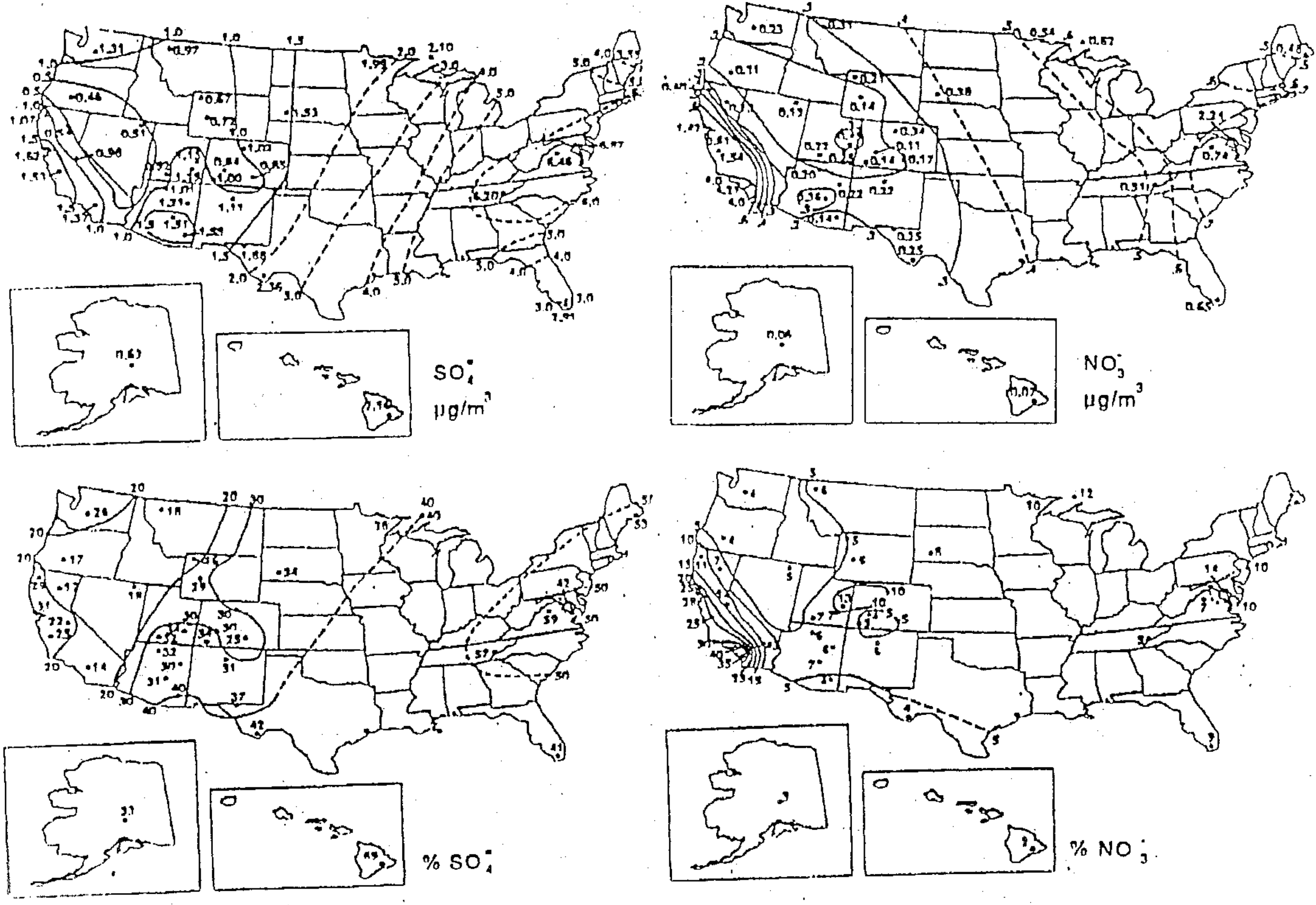
In contrast, coarse particles are large enough so that the force of gravity exceeds the buoyancy forces of the surrounding air currents leading to their settling out to the earth's surface. Coarse particles are in the 2.5 to 10 micron size range. These larger particles tend to fall rapidly out of the air, with atmospheric lifetimes of only minutes to hours depending on their size. Coarse particles are also too large to follow air streams, such that they tend to be easily removed by impaction on surfaces. Coarse particles are primarily composed of crustal elements (silicon, aluminum, iron and potassium); biological materials (bacteria, pollen, and spores) also appear in the coarse mode.

Emission Sources and Formation Processes of Particles

In most locations, a variety of diverse activities contribute significantly to PM concentrations, including fuel combustion (from vehicles, power generation, and industrial facilities), residential fireplaces, agricultural and silvicultural burning, and atmospheric formation from gaseous precursors (largely produced from fuel combustion). Other sources include construction and demolition activities, wind blown dust, and road dust. From these diverse sources come the mix of substances that comprise PM. The major chemical constituents of PM_{10} are sulfates, nitrates, carbonaceous compounds (both elemental and organic carbon compounds), acids, ammonium ions, metal compounds, water, and crustal materials. The amounts of these components vary from place to place and over time.

Coarse particles are primarily the result of crushing or grinding processes. Fine particles result from (1) direct emissions, (2) gaseous emissions which condense in the atmosphere without any other chemical reactions, and (3) precursor gases that later chemically react to form fine particles. Particles formed as a result of chemical reaction of gases are termed secondary particles because the direct emissions from a source is a gas (e.g., SO_2 or NO) that is subsequently converted to a low vapor pressure substance in the atmosphere. Sources of fine and coarse particles are summarized in Tables II-2 and II-3 (EPA, 1996). The fraction of fine particulate due to sulfate is greater in the East, and the nitrate fraction is larger in the West (see figure II-4; EPA, April 1996).

Transformation from gases to particles requires substantial interaction in the atmosphere. Such transformation can take place locally, during prolonged stagnations, or during transport over long distances. Moisture, sunlight, temperature, and the presence or absence of fogs and clouds affect transformation. In general, particles formed from these types of secondary processes will be more uniform in space and time than those that result from primary emissions.



Yearly average absolute and relative concentrations for sulfate and nitrate.

Source: Sisler et al. (1993) and Malm et al. (1994b).

Figure II-4

A large fraction of the mass in the fine size fraction is derived from material that has been volatilized in combustion chambers and then recondensed to form primary fine PM, or has been formed in the atmosphere from precursor gases as secondary PM. Since precursor gases and fine PM are capable of traveling great distances, it is difficult to identify precisely the contribution of the individual sources. Sulfuric acid, which is the source of particle strong acidity and sulfates, is formed from the atmospheric reaction of SO_2 which is formed during combustion of sulfur compounds contained in fossil fuels. As noted below, nitrates are formed by atmospheric reactions of NO_x which are generated during combustion or other high temperature processes. Ammonia, which neutralizes sulfuric and nitric acid to form sulfates and nitrates, has a variety of sources, the most important being emissions from animal waste and fertilizers.

PM may be formed from emissions of NO which are converted to NO_2 which then participates in various reactions to form other substances, including O_3 and PM. Nitrate airborne particles can be produced by several mechanisms. One major mechanism of nitrate formation involves nitric acid vapor which has a much higher vapor pressure than sulfuric acid and tends to stay more in the gas phase. Nitric acid (HNO_3) is mostly formed in the gas-phase reaction of NO_2 with the hydroxyl radical. The gaseous nitric acid can react with ammonia to form ammonium nitrate or at airborne particle surfaces to form nitrate salts, such as sodium nitrate. Thus, nitrate size distributions depend, in part, on the size distributions of the particles on which they react. Conditions that favor aerosol nitrate formation include high nitric acid concentrations, high ammonia (gas phase) or salt particle concentrations, low temperatures, and high relative humidity. If the air parcel carrying the aerosol nitrate experiences a temperature increase and/or decrease in humidity, the concentration of the aerosol nitrate would be expected to decline as the nitric acid or ammonia returns to gas phase. Fine particle nitrate concentrations near 100 micrograms per cubic meter over 24-hour averaging times have been observed in the eastern end of the South Coast Air Basin that surrounds Los Angeles during late October (Science and Technical Support Work Group, 1997).

Visibility-Impairing Particles

As described in the "Visibility Protection" section of this document, fine particles are effective in impairing visibility by scattering or absorbing light. Different types of particles have varying efficiencies in causing visibility impairment. The fine particles principally responsible for visibility impairment are sulfates, nitrates, organic matter, elemental carbon (soot), and soil dust. Coarse particles also impair visibility, although less efficiently than fine particles.

TABLE II-2 CONSTITUENTS OF ATMOSPHERIC FINE PARTICLES LESS THAN 2.5 MICRONS AND THEIR MAJOR SOURCES

	Sources			
	Primary PM		Secondary PM	
Aerosol species	Natural	Anthropogenic	Natural	Anthropogenic
$SO_4^{=}$	Sea spray	Fossil fuel combustion	Oxidation of reduced sulfur gases emitted by the oceans and wetlands; and SO_2 and H_2S emitted by volcanism and forest fires	Oxidation of SO_2 emitted from fossil fuel combustion
NO_3^-	—	Motor vehicle exhaust	Oxidation of NO_x produced by soils, forest fires, and lighting	Oxidation of NO_x emitted from fossil fuel combustion; and in motor vehicle exhaust
Minerals	Erosion, re-entrainment	Fugitive dust; paved, unpaved roads; agriculture and forestry	—	—
NH_4^-	—	Motor vehicle exhaust	Emissions of NH_3 from wild animals, undisturbed soil	Emissions of NH_3 from animal husbandry, sewage, fertilized land
Organic carbon	Wild fires	Open burning, wood burning, cooking, motor vehicle exhaust, tire wear	Oxidation of hydrocarbons emitted by vegetation, (terpenes, waxes); wild fires	Oxidation of hydrocarbons emitted by motor vehicles, open burning, wood burning
Elemental carbon	Wild fires	Motor vehicle exhaust, wood burning, cooking	—	—
Metals	Volcanic activity	Fossil fuel combustion, smelting, brake wear	—	—
Bioaerosols	Viruses, bacteria	—	—	—

TABLE II-3 CONSTITUENTS OF ATMOSPHERIC PARTICLES GREATER THAN 2.5 MICRONS AND THEIR MAJOR SOURCES

	Sources			
	Primary		Secondary	
Aerosol species	Natural	Anthropogenic	Natural	Anthropogenic
Minerals	Erosion, re-entrainment	Fugitive dust; paved, unpaved road dust, agriculture and forestry	—	—
Metals	Erosion, re-entrainment, organic debris	—	—	—
Miscellaneous ions	Sea spray	Road salting	—	—
Organic carbon	—	Tire and asphalt wear	—	—
Organic debris	Plant, insect fragments	—	—	—
Bioaerosols	Pollen, fungal spores, bacterial agglomerates	—	—	—

4. How much reduction is needed?

Implementing the PM_{10} Standards

As shown in figure II-3, there are still several PM_{10} nonattainment areas in the country. Some of these areas may need to consider decreases of NO_x emissions as part of their attainment planning. The importance of NO_x as a PM_{10} precursor varies significantly from place-to-place.

Integrated Strategies for Implementing the O_3 and PM Standards

Common Factors

As noted above, EPA published revisions to the O_3 and PM NAAQS on July 18, 1997. As part of the revisions process, EPA initiated action to address strategies for the implementation of the new NAAQS. These ongoing reviews and related implementation strategy activities to date have brought out important common factors between O_3 and PM. Similarities in pollutant sources, formation, and control exist between O_3 and PM, in particular the fine fraction of particles. These similarities provide opportunities for optimizing technical analysis tools (i.e., monitoring networks, emissions inventories, air quality models) and integrated emissions reduction strategies to yield important cross-cutting benefits across various air quality management programs. This integration could result in a net reduction of the regulatory burden on some source category sectors that would otherwise be impacted separately by O_3, PM, and visibility protection control strategies.

Federal Advisory Committee Act (FACA) Process

The EPA initiated a process designed to provide for significant stakeholder involvement in the development of integrated implementation strategies for the new/revised O_3 and PM NAAQS and a new regional haze program. As described below, this process involves a new subcommittee of the Agency's Clean Air Act Advisory Committee (CAAAC), established in accordance with the FACA (5 U.S.C. App.2). The CAAAC was established to provide independent advice and counsel to the EPA on policy and technical issues associated with the implementation of the Act. The CAAAC advises EPA on the development, implementation, and enforcement of several of the new and expanded regulatory and market-based programs required by the Act.

The CAAAC advises on issues that cut across several program areas. A new subcommittee of the CAAAC, the Subcommittee for Ozone, Particulate Matter, and Regional Haze Implementation Programs (the Subcommittee), was established in August 1995 to address integrated strategies for the implementation of the new O_3 and PM NAAQS, as well as a regional haze program. The focus of the Subcommittee will be on assisting EPA in developing implementation control strategies, preparing supporting analyses, and identifying and resolving impediments to the adoption of the resulting programs. The Subcommittee is composed of representatives selected from among state, local, and tribal organizations; environmental groups; industry; consultants; science/academia; and federal agencies. Recommendations made by the

APRIL 2000 ADDENDUM TO JUNE 1998 DIVISION OF WATER TECHNICAL AND OPERATIONAL GUIDANCE SERIES (TOGS) NO. 1.1.1. (Originator - Scott Stoner)

TABLE 1
NEW YORK STATE AMBIENT WATER QUALITY STANDARDS AND GUIDANCE VALUES
April 2000

SUBSTANCE (CAS No.)	WATER CLASSES	STANDARD (ug/L)	GUIDANCE VALUE (ug/L)	TYPE	BASIS CODE
Acetaldehyde (75-07-0)	A, A-S, AA, AA-S GA		8 8	H(WS) H(WS)	A A
n-Butanol (71-36-3)	A, A-S, AA, AA-S GA		50 50	H(WS) H(WS)	Z Z
Carbon disulfide (75-15-0)	A, A-S, AA, AA-S GA		60 60	H(WS) H(WS)	B B
Formaldehyde (50-00-0)	A, A-S, AA, AA-S GA		8 8	H(WS) H(WS)	A A
Methyl tert-butyl ether (MTBE) (1634-04-4)	A, A-S, AA, AA-S GA		10 10	H(WS) H(WS)	A A

TABLE 5
NEW YORK STATE GROUNDWATER EFFLUENT LIMITATIONS (CLASS GA)
April 2000

SUBSTANCE (CAS No.)	MAXIMUM ALLOWABLE CONCENTRATION (ug/L)	CATEGORY
Acetaldehyde (75-07-0)	8	B
n-Butanol (71-36-3)	50	B
Carbon disulfide (75-15-0)	60	B
Formaldehyde (50-00-0)	8	B
Methyl tert-butyl ether (MTBE) (1634-04-4)	10	B

In addition, n-butanol (listed synonymously as 1-butanol), carbon disulfide, formaldehyde and methyl tert-butyl ether are deleted from Table 3 of TOGS 1.1.1.

Philip De Gaetano for
N.G. Kaul, P.E.
Director
Division of Water

IDENTITY AND AUTHORITY OF THE AMICI CURIAE

Amici, the States of Connecticut, Maine, Massachusetts, New Hampshire and New York (collectively, the "Northeast states"), file this brief pursuant to Fed. R. App. P. 29(a) in support of California's appeal following EPA's denial of its request for a waiver from the Clean Air Act's oxygen requirement for reformulated gasoline.

INTEREST OF THE AMICI CURIAE

The Northeast states suffer smog from excess ground-level ozone in the summer. To reduce emissions of pollutants that contribute to ozone, as well as toxic emissions, gasoline dealers in some Northeast states are required to sell federal reformulated gasoline ("RFG"). The RFG program generally produces lower emissions of chemicals that lead to the formation of ozone and lower emissions of toxic chemicals by controlling the composition of RFG. One of the many parameters is that RFG must contain at least two percent oxygen by weight. In the Northeast, refiners have met this requirement primarily by adding the oxygenate methyl tertiary butyl ether ("MTBE") to RFG.

The Northeast states, like California, face a dilemma posed by unforeseen consequences of the oxygen requirement and the chemical properties of MTBE: either they continue to use MTBE in RFG and risk widespread contamination of drinking water or they use ethanol in RFG and emit more ozone-creating pollutants than RFG without any added oxygenates. For states to ensure both clean water and clean air, the U.S. Environmental Protection Agency ("EPA") must waive the oxygen requirement, as contemplated by the Clean Air Act ("CAA"), and allow the use of RFG without additional oxygen (which can still achieve the clean air benefits of the RFG program). Unfortunately, the EPA, in a case of first impression, applied an incorrect standard and a results-oriented analysis to California's waiver request. This precedent will interfere with the ability of the Northeast states to obtain waivers and to reduce emissions of ozone-causing chemicals.

FACTS

Ozone Threatens Public Health

Ozone is the prime ingredient of smog and adversely affects public health, especially the health of vulnerable groups such as children and the elderly. EPA, Ozone: Good Up High, Bad Nearby, EPA/451/k-97-002, (Oct. 1997) <http://www.epa.gov/oar/oaqps/gooduphigh/#affect>.

The CAA requires EPA to establish national air ambient quality standards ("NAAQS") for ozone and other harmful pollutants. 42 U.S.C. § 7409. The Northeast and California represent nearly half of the counties nationwide that are in nonattainment of the current one-hour ozone NAAQS. EPA, Classifications of Ozone Non-Attainment Areas, <http://www.epa.gov/oar/oaqps/greenbk/

onc.html>. EPA has established a more stringent eight-hour ozone NAAQS, see 62 Fed. Reg. 38856 (July 18, 1997),[1] and it is expected that even more areas, including areas in the Northeast, will be in nonattainment of this new ozone standard.[2]

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[1] The new ozone standard was recently upheld. American Trucking Ass'ns, Inc. v. EPA, 283 F.3d 355 (D.C. Cir. 2002).

[2] In addition, particulate matter air pollution is one of the most significant air quality and public environmental health issues, causing a wide range of adverse human health and environmental effects, from premature death to decreased visibility, and California and parts of the Northeast are in nonattainment of the particulate matter NAAQS. EPA, Particulate Matter Nonattainment State/Area/County, (Aug. 2, 2001) <http://www.epa.gov/oar/oaqps/greenbk/pncs.html>. EPA has established an additional and more restrictive particulate matter NAAQS that regulates particulate matter with a diameter of 2.5 microns or less ("PM-2.5") compared to the current standard of 10 microns ("PM-10"). See 62 Fed. Reg. 38651 (July 18, 1997). It is expected that many more areas, including some urban areas in the Northeast, will be in nonattainment of the PM-2.5 NAAQS than are currently in non-attainment of the PM-10 NAAQS.

The failure by any state to attain the ozone or other NAAQS will trigger possible sanctions, including loss of highway monies and federal takeover of the air quality planning process in the state. See Virginia v. EPA, 108 F.3d 1397, 1406 (D.C. Cir. 1997).

Reducing Emissions is Critical to Attaining Ozone NAAQS

Ozone is formed by a complex interaction of various chemicals. The main precursors to ozone formation are nitrogen oxides ("NOx") and volatile organic compounds ("VOCs"). EPA, Ozone: Good Up High, Bad Nearby, EPA/451/k-97-002, (Oct. 1997) <http://www.epa.gov/oar/oaqps/gooduphigh/#affect>; see generally 63 Fed. Reg. 57356, 57359 (Oct. 27, 1998) (discussing formation of ozone and its harmful effects); Virginia v. EPA, 108 F.3d at 1399-1400 (same). Until recently ozone control focused on reducing VOC emissions, but a National Academy of Sciences ("NAS") report commissioned by Congress, 42 U.S.C. § 7511f, found that "NOx control is necessary for effective reduction of ozone in many areas of the United States" and recommended that "the control of NOx emissions will probably be necessary in addition to, or instead of, the control of VOCs." NAS, Rethinking the Ozone Problem in Urban and Regional Air Pollution 11 (1991) <http://www.nap.edu/books/0309046319/html/index.html>. Other chemicals contribute to a lesser degree to ozone formation; it takes over 31 tons of carbon monoxide ("CO"), for example, to equal the ozone-forming potential of one ton of hydrocarbon [e.g., VOC] emissions. See Letter from California Air Resources Board to EPA (Sept. 20, 1999), Excerpt of Record Tab E, p. 4.[3]

The amici states have taken a number of increasingly stringent emission control and enforcement measures to reduce NOx and VOC emissions from stationary sources, including:

- cap and trade requirements for NOx emissions from power plants and other large sources of NOx pollution in the Ozone Transport Region, which includes the amici states, e.g., 6 New York Code of Rules and Regulations ("NYCRR") Part 204 & Subpart 227-3 (2001);
- controls in State Implementation Plans ("SIPs") on NOx emissions from new sources, and requiring offsets by greater emission reductions from existing sources;
- VOC vapor controls at gas stations and marine terminals, e.g., NYCRR Parts 299, 230;
- limits on VOC emissions from cement plants, petroleum refineries, steel plants, incinerators, petroleum storage facilities, pharmaceutical and cosmetic manufacturing processes, bakeries and printers, e.g., 6 NYCRR Parts 212, 216, 219, 220, 223, 228, 229, 233 and 234;

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[3] NOx is also one of the principal precursors to particulate matter formation.

- rules lowering the amount of VOCs in hair sprays, deodorants, architectural coatings, house paints, swimming pool coatings and varnishes, e.g., 6 NYCRR Part 205; and

- obtaining a Section 126 ruling from EPA that requires extensive reductions of NOx emissions from power plants across the eastern half of the United States, 65 Fed. Reg. 2674 (Jan. 18, 2000), which was upheld on appeal, Appalachian Power Co. v. EPA, 249 F.3d 1032 (D.C. Cir. 2001).

Notably, in a rule limiting NOx production in states upwind of the Northeast, EPA recognized that control of both NOx and VOCs is crucial to achieving the ozone standard, and rejected arguments that VOC reductions could be substituted for NOx reductions. See 63 Fed. Reg. 57356, 57370 (Oct. 27, 1998).

States Must Control Emissions from Mobile Sources

These actions regarding statutory sources alone, however, are insufficient to attain the ozone NAAQS in all areas. EPA evaluates states' NAAQS attainment demonstrations based upon the aggregate reduction from all emissions sources, both mobile and stationary. Mobile sources are the largest source of NOx emissions and one of the largest sources of VOCs. Accordingly, the ozone SIPs for most Northeast states rely heavily upon control of mobile sources through the RFG program .

Congress created the RFG program in the 1990 Clean Air Act amendments to reduce ozone-forming chemicals as well as toxic air pollutants. See U.S.C. § 7545(k). Among other things, the RFG program restricts or eliminates the amount of benzene, aromatics, lead, manganese and other heavy metals in RFG. See 42 U.S.C. §§ 7545(k)(2), (3). And RFG must be formulated to reduce emissions of VOCs and toxic air pollutants. 42 U.S.C. § 7545(k)(3)(B). Congress recognized the importance of NOx in the formation of ozone and mandated that the use of RFG must, at a minimum, not increase NOx emissions. See 42 U.S.C. § 7545(k)(2)(A). Indeed, advances in EPA's understanding of the role of NOx emissions have prompted the Agency to require a 6% decrease in NOx emissions for Phase II RFG. See 40 C.F.R. § 80.41(f).

Congress also required that RFG contain at least 2% oxygen by weight. 42 U.S.C. § 7545(k)(2)(B). This requirement was passed partly to promote more complete combustion and reduce polluting emissions and partly to create an additional market for corn products such as ethanol. See Sen. Comm. on Env't and Pub. Works, I A Legislative History of the Clean Air Act Amendments of 1990 1267, 1303 (1993) (excerpts from Congressional debate). Yet Congress judged that the CAA's overriding goal of clean air must trump other, subordinate policies behind the oxygen mandate, and explicitly created mechanisms for EPA to waive the oxygen mandate if its continuation "would prevent or interfere with the attainment by the area of a national primary ambient air quality standard," 42 U.S.C. § 7545(k)(2)(B).

See also 42 U.S.C. § 7545(k)(2)(A) (allowing waiver of oxygen requirement if it increases NOx emissions).

Areas in "severe" nonattainment of the ozone NAAQS are required to use RFG. See 42 U.S.C. § 7545(k)(10)(D). The designated metropolitan areas that must use RFG in the Northeast include the New York City metropolitan area (including northeast New Jersey and southwestern Connecticut), the greater Hartford area, and the Philadelphia consolidated metropolitan statistical area (including portions of New Jersey). EPA, List of Reformulated Gasoline Program Areas (Jan. 5, 2001) <http://www.epa.gov/otaq/rfgarea.html>. Other ozone nonattainment areas may voluntarily "opt in" to the RFG program to control ozone. 42 U.S.C. §§ 7545(k)(1), (k)(6). Such areas in the Northeast that have opted into the RFG program include portions of Connecticut, New Jersey, New York, New Hampshire, and Maine and the entire states of Massachusetts and Rhode Island. EPA, List of Reformulated Gasoline Program Areas (Jan. 5, 2001) <http://www.epa.gov/otaq/rfgarea.htm>.

MTBE Has Been Used to Meet the Oxygen Requirement in the Northeast and California

Although neither the CAA nor EPA regulations require the use of any particular oxygenate to meet the minimum oxygen levels of the RFG program,[4] refiners commonly blend in either MTBE or ethanol to meet this requirement. In the Northeast, as in California, refiners have used MTBE almost exclusively to satisfy the oxygen requirement in RFG because it is relatively inexpensive, has clean-burning characteristics, provides a good source of octane and can be shipped through existing pipelines. See Northeast States for Coordinated Air Use Management ("NESCAUM"), RFG/MTBE Findings & Recommendations 11 (Aug. 1999) <http://www.nescaum.org/pdf/MTBE_PH2/Ph2summ.pdf> ("NESCAUM MTBE

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[4] EPA merely certifies that gasoline with various concentrations of additives, including MTBE, is either "substantially similar" to certain baseline fuel or does not impair emission control devices. 42 U.S.C. § 7545(f)(4); see 46 Fed. Reg. 38582 (July 28, 1981); 44 Fed. Reg. 12242 (Mar. 6, 1979). EPA's determination, while a necessary precondition to the use of certain gasoline, does not constitute authorization or approval of MTBE. Indeed, MTBE producers must provide a binding assurance to EPA that they will not in any manner "represent . . . that registration of the additive constitutes endorsement, certification, or approval by any agency of the United States." 40 C.F.R. § 79.21(g).

Report"). Approximately three-quarters of all gasoline sold in the Northeast is RFG, requiring the use of over one billion gallons of MTBE in the region every year. Id.[5]

MTBE Contaminates Drinking Water

Over the past decade, public health authorities have realized that an unforeseen consequence of increased MTBE use in RFG is a parallel increase in MTBE contamination of groundwater. As the EPA noted, "existing information on contamination of drinking water resources by MTBE indicates substantial evidence of a significant risk to the nation's drinking water supply." Advance Notice of Intent To Initiate Rulemaking Under the Toxic Substances Control Act To Eliminate or Limit the Use of MTBE as a Fuel Additive in Gasoline, 65 Fed. Reg. 16094, 16095 (Mar. 24, 2000). About 9 million gallons of gasoline are leaked or spilled into the U.S. environment every year, id. at 16098, and a significant portion of this gasoline contains MTBE. Once spilled, MTBE moves rapidly through soil and contaminates groundwater because it is highly soluble and resistant to biodegradation, much more so than other hazardous gasoline components such as benzene, toluene, ethylbenzene and xylenes. Id. at 16097. For these reasons, a nationwide study by the

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[5] Refiners also add much smaller quantities of MTBE and ethanol to conventional gasoline to boost octane and thereby reduce engine knock.

U.S. Geological Survey ("USGS") detected MTBE in 21% of ambient groundwater where MTBE is used in RFG, compared with 2% in areas using conventional gasoline. Id. at 16099.

This widespread MTBE contamination threatens public health because groundwater is used as drinking water by 40 to 46% of the U.S. population, and concentrations of MTBE as low as 2.5 parts per billion ("ppb") for odor and 2 ppb for taste in drinking water can render it unpotable with an unpleasant turpentine-like taste and odor. Id. at 16097.[6] In fact, drinking water supplies in the Northeast have already been affected by MTBE. A joint USGS/EPA study of 12 Northeastern states found that MTBE was detected in 7% of the region's drinking water supplies, and was detected five times more frequently in drinking water in areas where gasoline must contain oxygenates than in other areas. Id. at 16099. Another study

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6. MTBE may pose other health threats but the scientific evidence is not yet definitive. Id. at 16098. Nonetheless, Congress has listed MTBE as a hazardous air pollutant, 42 U.S.C. § 7412(b)(1), and the EPA has classified MTBE as a possible human carcinogen, 65 Fed. Reg. at 16098, has designated MTBE as a proposed mobile source toxic, 65 Fed. Reg. 48058, 48067 Table II-1 (Aug. 4, 2000), and has proposed listing MTBE as a contaminant "of special interest" under the Safe Drinking Water Act because of its potential for contaminating drinking water, 62 Fed. Reg. 52194, 52211 (Oct. 6, 1997).

by the Northeast states found MTBE at low levels in about 15% of the region's drinking water. NESCAUM MTBE Report, p. 14.[7]

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[7] In addition, a 1998 Maine study found that MTBE was present in 15.8% of sampled household wells and 16% of public water systems. 65 Fed. Reg. at 16100. In New Hampshire, MTBE has been detected in 15.2% of active public water systems In New York, a survey found MTBE in groundwater at 32% of 5,262 reported gasoline spills at which remediation is underway, and that MTBE has already affected the water supply of at least 178,671 New Yorkers. Survey of Active New York State Gasoline Remediation Sites with Potential MTBE Contamination, at p. 2, Table 4 (Feb. 8, 2000) <http://www.dec.state.ny.us/website/der/mtbesurv.pdf.

Although only a small percentage (.5 to 1.5%) of MTBE detections in the Northeast's drinking water to date are above current applicable standards,[8] the amici states are concerned about the serious potential for drinking water contamination because groundwater supplies in the Northeast are typically drawn from fractured bedrock aquifers or sand and gravel aquifers that are susceptible to groundwater contamination. NESCAUM MTBE Report, p. 17.

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[8] The EPA has issued a non-regulatory advisory that MTBE should be kept below 20 to 40 ppb, 65 Fed. Reg. at 16097, but the taste and odor problems and possible health concerns at lower concentrations have prompted states to impose more restrictive standards. For example, California established a secondary drinking water standard of 5 ppb and has proposed a primary health-based standard of 13 ppb, id. at 16097 and 16098, New Hampshire has proposed a primary health-based standard of 13 ppb, id. at 16098, and New York has reduced groundwater remediation guidance values for MTBE from 50 ppb to 10 ppb, and is similarly revising the drinking water standard, New York Department of Environmental Conservation, Technical & Operational Guidance Series 1.1.1, Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations Table 1 (Apr. 2000).

The Northeast States' Strategies to Limit MTBE and to Protect Their Drinking Water

EPA convened a Blue Ribbon Panel to evaluate the considerable evidence regarding water contamination from MTBE. The Panel concluded that "MTBE is detected ten times more often in drinking water from community water systems in areas that use [RFG] or [the related Oxyfuel program] than in non-RFG/[Oxyfuel] areas." EPA Blue Ribbon Panel, Achieving Clean Air and Clean Water: The Report of the Blue Ribbon Panel on Oxygenates in Gasoline (Sept. 15, 1999), Excerpts of Record Tab O ("Blue Ribbon Report"), pp. 14-15. The Blue Ribbon Panel recommended that MTBE be phased out of RFG, id., pp. 13-21, 86, 88, by, among other things, the immediate removal of the RFG program's oxygen mandate, id., p. 87. EPA began to implement the Panel's recommendations by initiating a rulemaking under the Toxic Substances Control Act to limit or eliminate use of MTBE in gasoline. 65 Fed. Reg. 16094 (Mar. 24, 2000).

Unable to wait for federal action while their water supplies are threatened, a number of the Northeast states have followed California and taken action to reduce MTBE use. Connecticut and New York have banned MTBE by October 1, 2003 and January 1, 2004 respectively, and other states are considering similar steps. In addition, voluntary RFG areas in the Northeast may choose to opt out of the program entirely to avoid MTBE contamination: Maine opted out of the RFG program for this reason in 1999, and other voluntary RFG areas will likely opt out as soon as they are able. See 40 C.F.R. 80.72 (2000) (opt-in states must remain in RFG program until 2004). Indeed, New Hampshire has asked EPA for permission to opt out of the RFG before 2004.

The Oxygen Requirement is Not Necessary to Have Cleaner-Burning RFG

Upon eliminating MTBE, the Northeast states, like California, face a de facto requirement to use ethanol in RFG because it is the only other oxygenate available in sufficient quantities. But California's study of fuels has established that RFG with ethanol will increase NOx emissions compared to RFG with MTBE, which pollutes water, or compared to new RFG that would not use any oxygenates while meeting the other statutory requirements of the RFG program, such as caps on emissions of NOx, VOCs and toxic air pollutants and limits on the allowable concentrations of benzene, aromatic hydrocarbons and heavy metals in RFG. See 42 U.S.C. §§ 9545(k)(2), (3). Based on its evidence that RFG containing ethanol will worsen air emissions, California sought a waiver of the oxygen requirement from EPA and, when EPA denied the waiver, appealed directly to this Court.

The Northeast states have analyzed RFG with ethanol and agree with California – the large-scale use of ethanol is likely to increase ozone.[9] Specifically, gasoline with ethanol blended at high volumes produces both greater tailpipe emissions of NOx and greater evaporative emissions of VOCs and other toxics due to (1) the relatively high volatility of ethanol-blended fuel, (2) commingling of ethanol and non-ethanol blends in vehicle fuel tanks, (3) increased fuel permeation through fuel lines and hoses, (4) reduced effectiveness of on-board vapor recovery systems and (5) increased truck and barge traffic to transport ethanol to and within the region. NESCAUM, II Health, Environmental and Economic Impacts of Adding Ethanol to Gasoline in the Northeastern States 10-16 (2001) <http://www.nescaum.org/committees/ethanol-report.html>.

Alternatively, it is technically feasible to produce RFG without oxygenate additives that achieves air quality benefits equivalent to or greater than those produced by RFG with oxygen from the addition of MTBE or ethanol, including lower NOx emissions.[10] California's Phase 3 Cleaner-Burning Gasoline, for example,

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9. Such fuel is also likely to increase particulate matter emissions.

10. Potential non-oxygenate alternatives to MTBE include alkylates and iso-octane, which provide octane without apparent increases in toxic emissions. As long as the oxygen mandate is in effect, however, refiners are unlikely to assess the full environmental and public health impacts of non-oxygenate replacements to avoid the unanticipated effects that have plagued MTBE. Further, refiners will not invest in production capabilities to make sufficient quantities of these oxygenate alternatives

does not contain oxygenates and is cleaner burning than RFG with added oxygenates. And New Hampshire has filed a petition with EPA to opt out of the RFG program and to substitute its own fuel program, which will not require a minimum oxygen content.

The amici have a specific interest in avoiding the Hobson's choice between more polluted air (attributable to ethanol use) and more polluted water (attributable to MTBE use). In order to attain current NAAQS, let alone comply with EPA's more stringent planned NAAQS for ozone, the Northeast states will be required to maximize both NOx and VOC reductions from mobile sources through the RFG program in order to make the necessary deep cuts in emissions of ozone precursor chemicals. Because ethanol-containing RFG will jeopardize these plans, New York and Connecticut are preparing waiver requests, and other Northeast states may also file waiver requests.

ARGUMENT

I. EPA APPLIED AN INCORRECT STANDARD AND SPECULATIVE ANALYSIS TO CALIFORNIA'S WAIVER REQUEST

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until the mandate is lifted.

A court may set aside an EPA decision as arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with the law, 5 U.S.C. § 706(2), where, for example, the Agency has "relied on factors which Congress has not intended it to consider, entirely failed to consider an important aspect of the problem, [or] offered an explanation for its decision that runs counter to the evidence before the agency . . . ." Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 43 (1983). In denying California's request for a waiver of the oxygen mandate, EPA made three errors in construing the CAA standard. First, EPA required California to "clearly demonstrate" that a waiver would improve NAAQS attainment, rather than apply the less stringent CAA standard, which simply requires a showing that the oxygen requirement "interferes with" attainment of a NAAQS. Second, EPA compounded this error by using a flawed analysis of a waiver's impact on the ozone NAAQS and by improperly discounting California's clear evidence that a waiver would result in lower NOx emissions. Third, EPA ignored the general CAA command to consider the effect of the oxygen requirement for each applicable NAAQS independently, instead requiring California to show that all applicable NAAQS would be interfered with and ignoring California's argument and evidence that the oxygen requirement would interfere with the particulate matter (PM-10) NAAQS. For these reasons, EPA's decision was arbitrary and capricious.[11]

A. EPA's "Clearly Demonstrated" Standard is Contrary to the CAA

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[11] While amici address EPA's stated reasons for denial in this brief, it has been reported that EPA denied California's waiver request and forced the use of ethanol only after the Administration was heavily lobbied by lawmakers, governors and agricultural trade groups who support the creation of ethanol markets and the resulting higher prices for corn. See Support Grows for Corn-Based Fuel Despite Critics, New York Times, July 23, 2001, p. A1.

Under the CAA, waiver is warranted when the oxygen requirement "would prevent or interfere with the attainment by the area of a national primary ambient air quality standard." 42 U.S.C. § 7454(k)(2)(B) (emphasis added). In its preliminary analysis, EPA admitted that "interfere with" is a relatively low evidentiary threshold satisfied by "an effect that makes achieving the NAAQS more difficult, but that does not itself necessarily prevent attainment." Technical Support Document: Analysis of California's Request for Waiver of the Reformulated Gasoline Oxygen Content Requirement for California Covered Areas, Excerpt of Record Tab L ("Technical Support Document"), p. 131.[12]

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[12] For example, delay in attaining a NAAQS would be interference even if attainment is not ultimately prevented. That reading of the statutory "interferes with" standard is consistent with Train v. Natural Resources Defense Council, Inc., 421 U.S. 60, 90 (1975), in which the Court stated that EPA should not approve a SIP revision, which requires a showing of non-interference with a NAAQS, if the revision "would no longer ensure timely attainment of the national standards." And, as this Court has noted, EPA has subsequently applied a delay standard in considering whether to approve SIP revisions. Hall v. EPA, 273 F.3d 1146, 1158 (9th Cir. 2001).

In its final analysis, however, EPA explained that interference would be shown if "the impacts of a waiver are clearly demonstrated for each applicable NAAQS." EPA, Analysis of and Action on California's Request for a Waiver of the Oxygen Content in Gasoline (June 2001), Excerpt of Record Tab K ("Analysis"), p. 3 (emphasis added). EPA further it required California to make "a clear demonstration that the changes in emissions resulting from a waiver would have a beneficial impact for purposes of attaining one NAAQS, and would not hinder attainment for any other NAAQS." Technical Support Document, p. 145 (emphasis added).

The burden of proof required by EPA is not a reasonable interpretation of the CAA's "interfere with" standard and therefore is due no deference by this Court. See Chevron USA, Inc. v. Natural Resources Defense Council, Inc., 467 U.S. 837 (1984).[13] EPA required California to meet a "clear demonstration" burden of proof and effectively required California to prove that there were no uncertainties about whether a waiver would produce air benefits. EPA's "clear demonstration" test was akin to the "clear and convincing" evidence standard reserved for special

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13. Amici would not take issue with EPA's restatement of the standard as requiring a "beneficial impact" if that were taken as merely the converse of demonstrating no interference. But the burden of proof required by EPA makes clear that "beneficial impact" is different than the "interferes with" standard.

circumstances, if not akin to the "beyond a reasonable doubt" test reserved for criminal matters.

Given that the CAA waiver provision is silent as to the burden of proof, standard rules of construction dictate that California only need show interference by a preponderance of the evidence. See Bender v. Clark, 744 F.2d 1424, 1429-30 (10th Cir. 1984) (rejecting agency's use of "clear and definite" standard to determine bid for mineral lease that did not involve particularly important individual rights, and imposing preponderance of the evidence standard even though agency action was not governed by Administrative Procedure Act § 556(d)). See generally Richard J. Pierce, II Administrative Law Treatise § 10.7 at 763-66 (4th ed. 2002). Accordingly, EPA's "clear demonstration" standard was an improper application of the CAA's waiver provision.[14] Indeed, EPA's stringent standard undermines the waiver mechanism Congress intended to protect states from the unintended consequences of the oxygen mandate.

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[14] As EPA admits, its interpretation thereby raised the level of proof for interference to at least that required for a SIP state fuel control that must be "necessary to achieve" a NAAQS under 42 U.S.C. § 7545(c)(4)(C). Technical Support Document, p. 145.

Not only did the high evidentiary burden created by EPA preordain that California's waiver request would be denied, but it is inconsistent with the longstanding deference that Congress and EPA have given to California's air pollution control programs, especially with regard to motor vehicles and fuels. See 42 U.S.C. § 7543(b) (no preemption of California vehicle emission controls); 42 U.S.C. § 7545(c)(4)(B) (no preemption of California requirements for fuels and fuel additives). California has the most effective mobile-source emission control program in the world, and California's technical analysis is viewed with great deference by other states and by affected industries.

B. EPA's Disregard of NOx and Reliance on Inconclusive Predictions for VOC Emissions Was Arbitrary and Capricious

EPA's denial was also flawed on substantive grounds because the Agency ignored the importance of NOx emissions. In order to attain the ozone NAAQS, California must obtain NOx emission reductions from every available source. California's petition therefore emphasized that additional NOx reductions from mobile sources were needed beyond those commitments in its recently approved SIP, that a waiver would allow California to achieve those reductions, and conversely that rejection of a waiver and the resulting use of ethanol-RFG would increase NOx emissions and interfere with attainment of the ozone NAAQS. EPA agreed with

California's prediction for NOx emissions, stating that its own analysis "shows a likely decrease of NOx under all scenarios [with a waiver] examined . . . ." Analysis, p. 8.[15] Since NOx is one of the two important precursors causing ozone, and maximizing NOx reductions is crucial to controlling ozone, EPA should have granted California's waiver request.

In the face of unequivocal evidence that NOx emissions will increase with the use of ethanol, however, EPA denied California's waiver request because the Agency predicted that a waiver would increase CO emissions and, more importantly, might either increase or decrease VOC emissions. Analysis, pp. 9-12. This analysis – which improperly looked beyond whether the oxygen requirement "interferes with" NAAQS attainment – is flawed for two additional, substantive reasons.

First, EPA overestimated the impact of CO on ozone formation. Although NOx, VOCs and CO all contribute to ozone formation, NOx and VOCs each have a much greater effect on the formation of ozone than the equivalent amount of CO. See Letter from California Air Resources Board to EPA (Sept 20, 1999), Excerpt of

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[15] Although EPA states that its finding that a waiver would reduce NOx emissions "is unique to California's regulatory structure and specific to California refineries' technical configurations," id., the Northeast states will also be able to show that waivers will reduce NOx emissions.

Record Tab E, p. 4 (one ton of hydrocarbons makes the same contribution, on average, as thirty-one (31) tons of CO). EPA considered the relative contributions that VOCs and CO make to ozone formation, see Technical Support Document, p. 126, n. 88, and concluded that the relative reactivity factors meant that VOC decreases alone would completely or partially offset any CO increases in ten out of twelve predicted scenarios. But EPA did not then consider the relative importance of NOx compared to CO in ozone formation. Given the unquestioned reductions in NOx emissions with a waiver, and the much greater importance of NOx to ozone formation compared to CO, any CO increases not already offset by VOC reductions would have been offset by the NOx emission reductions. It was arbitrary for EPA to ignore this effect.

Second, EPA improperly used uncertain VOC predictions to negate the unequivocal reduction in NOx emissions that would result from a waiver. EPA's predictions regarding VOC emissions were, in its own words, "mixed": with a waiver, exhaust VOC emissions would increase but evaporative emissions and permeation emissions (from fuel escaping through fuel system components) would decrease. In fact, in balancing these effects, EPA concluded that "the net result of these opposite exhaust and non-exhaust effects would be a reduction in VOC emissions with a waiver, though the magnitude of the reduction varies across scenarios [using RFG]." Analysis, p. 9 (emphasis added).[16]

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[16] The Northeast states also believe that EPA greatly underestimated the increase in permeation emissions from ethanol-oxygenated RFG and the increase in indirect emissions from the transport of ethanol by diesel trucks and barges from the Midwest.

After reaching this conclusion, however, EPA speculated that the commingling of ethanol-oxygenated RFG with non-ethanol gasoline in the gasoline tanks of California cars might increase net VOC emissions. Analysis, pp. 9-12.[17] It is undisputed that a mixture of ethanol-oxygenated gasoline and non-oxygenated gasoline will have a higher volatility than either of the two gasolines alone, and that this commingling effect will increase VOC emissions to some extent. Where MTBE is banned, more ethanol will likely be used to boost octane in both RFG and conventional gasoline markets, thereby increasing the likelihood of commingling because some people will fill up their cars with gasoline in different areas. But as EPA conceded, the "magnitude [of the commingling effect] is very difficult to forecast as it depends upon estimates of the oxygenated/non-oxygenated market share, the oxygen content used in ethanol-oxygenated RFG, and vehicle owners' refueling behavior (including brand loyalty and full versus partial fill-ups), among other

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17. Federal and state regulations prohibit commingling in the fuel distribution system, so any commingling will principally occur through the behavior of consumers, who are not regulated in this respect. However, dealers may buy gasoline from low bidders without regard to commingling restrictions, and compliance surveys of gas stations have found samples with significant amounts of both ethanol and MTBE.

variables," and the variables "have been only crudely estimated." Analysis, pp. 10, 12.

In addition to relying on "crude estimates" of commingling for its net VOC increase speculation, EPA did not even suggest that a waiver would affect that ultimate net result. Even without a waiver, the extent to which drivers will fill up with both RFG and regular gasoline is a crucial assumption. For example, Californians who work in the greater Los Angeles and Sacramento RFG areas and live outside those areas might be expected to fill up their cars with non-oxygenated gasoline where they live and ethanol-oxygenated RFG where they work, which would create a significant cross-border commingling effect in the absence of a waiver. Indeed, these commuters might be expected to drive long distances every day and thus compound the commingling effect. But EPA ignored the difference in the magnitude of cross-border commingling with and without a waiver. Id., n. 8. This omission allowed EPA to predict that "there would be no appreciable commingling effects" without a waiver because all of the gasoline in RFG areas would contain ethanol. Id., p. 10. EPA's flawed baseline in turn made it easier for the Agency to conclude that a waiver would increase the commingling effect.

EPA's commingling errors would be even more arbitrary if applied by the Agency to deny oxygen waiver petitions from Northeast states. The gasoline market in the Northeast consists of many political and air quality jurisdictions, including

RFG areas where oxygenates are required and conventional gasoline areas where oxygenates are not required. Northeast commuters travel across separate fuel areas on a daily basis, the main travel corridors like Interstate 95 cut across different fuel areas, and different state and county gasoline taxes likely induce strategic filling behavior by drivers. The Northeast distribution system may also induce "spillover," the phenomenon where RFG is sold in non-RFG areas as conventional gasoline simply because it is cheaper to sell one gasoline than to establish separate distribution systems. Accordingly, amici expect that if EPA were to deny waiver petitions from Northeast states, ethanol-oxygenated RFG in the Northeast would create a greater commingling effect than in California and, conversely, that waivers would not appreciably increase the commingling effect in the Northeast. EPA's failure to consider cross-border effects in the Northeast would therefore artificially inflate the likelihood of an increase in VOC emissions with a waiver and underestimate the important benefits of NOx reductions.

EPA acknowledged that "the impact of a waiver on VOC emissions is considerably more complex to model" than the impact on NOx and CO emissions. Analysis, p. 12. The vulnerability of commingling predictions to different assumptions means that this Court must carefully scrutinize EPA's methods for results-oriented analysis and should demand that EPA use a more rigorous analysis.

On the record before it, this Court should determine that EPA's reliance on commingling and "crudely estimated" assumptions was arbitrary and capricious.

C. EPA's Failure to Consider Whether the Oxygen Requirement Interferes with Attainment of the Particulate Matter NAAQS is Contrary to the CAA

EPA also acted arbitrarily by declining to reach California's argument that the oxygen requirement would interfere with the PM-10 NAAQS. See Analysis, p. 14, n. 15. The CAA clearly provides that waiver is warranted when the oxygen requirement "would prevent or interfere with the attainment by the area of a national primary ambient air quality standard." 42 U.S.C. § 7454(k)(2)(B) (emphasis added). Rather than perform a separate, independent analysis for the ozone and PM-10 NAAQS, however, EPA stated that it "should not grant a waiver unless the impacts of a waiver are clearly demonstrated for each applicable NAAQS." Analysis, p. 3 (emphasis added). EPA's standard meant that California's petition would fail if EPA did not accept its proof of interference with all applicable NAAQS. Thus, when EPA rejected California's ozone argument, it declined to reach California's alternative PM-10 argument. See Analysis, p. 14, n. 15. EPA's omission violated the CAA's command to analyze each affected NAAQS.

Had EPA considered the merits of the particulate matter argument, California clearly would have met the statutory test for waiver. The Agency has not challenged California's evidence that NOx emissions will be higher without a waiver than with a waiver and has long acknowledged that NOx is a key precursor to the formation of particulate matter. E.g., EPA, Nitrogen Oxides: Impact on Public Health and the Environment 52-64 (1997). Indeed, NOx is the single most important precursor to particulate matter formation in California, and increased NOx emissions will interfere with attainment of the PM-10 NAAQS. Even under EPA's more stringent and thus incorrect "clear demonstration" test, California should win because it has shown "that the changes in [NOx] emissions resulting from a waiver would have a beneficial impact for purposes of attaining . . . [the PM-10] NAAQS, and would not hinder attainment for any other [e.g., ozone] NAAQS." See Technical Support Document, p. 145.

EPA's failure to consider whether the oxygen mandate interferes with attainment of the PM-10 NAAQS is even more egregious because recent EPA studies show that exposure to fine particulate matter, due largely to emissions of NOx and sulfur dioxide from combustion sources like motor vehicles and power plants, causes increased mortality and chronic respiratory illness at a great cost to society. See EPA, The Benefits and Costs of the Clean Air Act, 1970-1990 52, Table 16 (1997) <http://www.epa.gov/oar/sect812/chptr1_7.pdf> (valuing the mortality and chronic bronchitis reductions attributable to particulate matters reductions as approximately $20 trillion). Indeed, the high costs of particulate matter pollution prompted the EPA's more stringent PM-2.5 NAAQS. See 62 Fed. Reg. 38651 (July 18, 1997).

Since EPA disregarded the PM-10 NAAQS and has therefore "entirely failed to consider an important aspect of the problem," see State Farm, 463 U.S. at 43, the Agency's dismissal of California's waiver petition was arbitrary and capricious and should be vacated and remanded.

II. EPA'S DENIAL WILL FORCE STATES TO CHOOSE BETWEEN CLEAN WATER AND CLEAN AIR AND WILL PRECLUDE REGIONAL SOLUTIONS

EPA's errors in denying California's waiver request – the first submitted under the CAA – have national effects.

Without the ability to obtain a waiver, states that now use RFG will have the unfortunate choice between allowing their drinking water supplies to be threatened by MTBE and using ethanol and suffering worse air pollution. Widespread MTBE contamination in the Northeast, for example, has caused states to ban or strictly limit MTBE to protect drinking water. And the use of ethanol, the only oxygenate currently available in quantities that are potentially sufficient to meet the RFG program's oxygen requirement, will worsen air quality compared to RFG that is designed to be clean burning without the addition of oxygen. Yet EPA's arbitrary standard for granting a waiver makes it more difficult for Northeast states to obtain waivers and thereby jeopardizes their efforts to attain the ozone and particulate matter NAAQS.

In addition, the oxygen requirement precludes effective regional solutions for reducing ozone pollution, one of the major goals of the CAA. E.g., 42 U.S.C. § 7406 (encouraging formation of interstate air quality agencies), 42 U.S.C. § 7426 (establishing procedures for states to abate interstate pollution), 42 U.S.C. § 7506a (authorizing interstate transport commissions). The CAA specifically requires the Northeast states to work together on the ozone nonattainment problem. 42 U.S.C. § 7511c (establishing Northeast ozone transport commission). The Northeast states already cooperate extensively on air quality issues and are well suited to developing a regional market for RFG without oxygen that can be tailored to the regional airsheds and ozone problem. But unless the EPA grants waivers, the mandatory RFG areas in the Northeast – greater New York, Hartford and Philadelphia – will not be able to participate in a regional market for such fuels. EPA's denial of waivers would instead fragment the Northeast gasoline markets between mandatory RFG areas and voluntary RFG areas that will likely opt out and use fuels that do not contain added oxygen.

Finally, the Northeast states must maximize NOx reductions from mobile sources because they are already pursuing other efforts to obtain NOx reductions from stationary sources in their jurisdiction and in upwind states. EPA should not preclude maximum NOx reductions by forcing states to use gasoline with an ethanol additive.

CONCLUSION

States are legally obligated both to achieve compliance with the ozone and particulate matter NAAQS and to protect public health and natural resources from MTBE contamination. These goals cannot be achieved without relief from the oxygen mandate, but EPA's denial of the California oxygen waiver request sets an unreasonably high standard that goes far beyond the CAA and relies upon arbitrary assumptions.