California Environmental Protection Agency
Air Resources Board

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

May 28, 2002
(2nd Draft)

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

AIR RESOURCES BOARD
Stationary Source Division

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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 denatured 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 accordingly 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 in the range between 25 to 65 percent, the modeling work predicted average RVP increases of 0.06-0.08 psi and 0.07-0.09 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 $\pm$ 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 of less than 0.07psi.

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 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 areas of the state: Lake Tahoe, San Francisco, 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 (UCD).

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 in 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.

[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 U.S. EPA as a "severe" ozone non-attainment area and will have to use federal RFG beginning 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.

[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	^{o}F	213	203	225
T90	^{o}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.

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.

<u>Field Study Areas:</u> 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 San Francisco 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 there are ethanol-blended fuels currently being marketed throughout California, they represent only a small fraction of the total statewide supply. However, due to the voluntary early phase out of MTBE in the Lake Tahoe area, ethanol blended fuels are 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 San Francisco 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 area:

- **San Francisco 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 San Francisco 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, San Francisco, 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
San Francisco	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 San Francisco 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) is 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 occurs in three areas:

1. A quality control standard of known composition is analyzed at the beginning and end of each day's analyses. The QC standard is also run after every 10 samples if more than 10 samples are 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 is 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 is 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 C. 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	SF 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

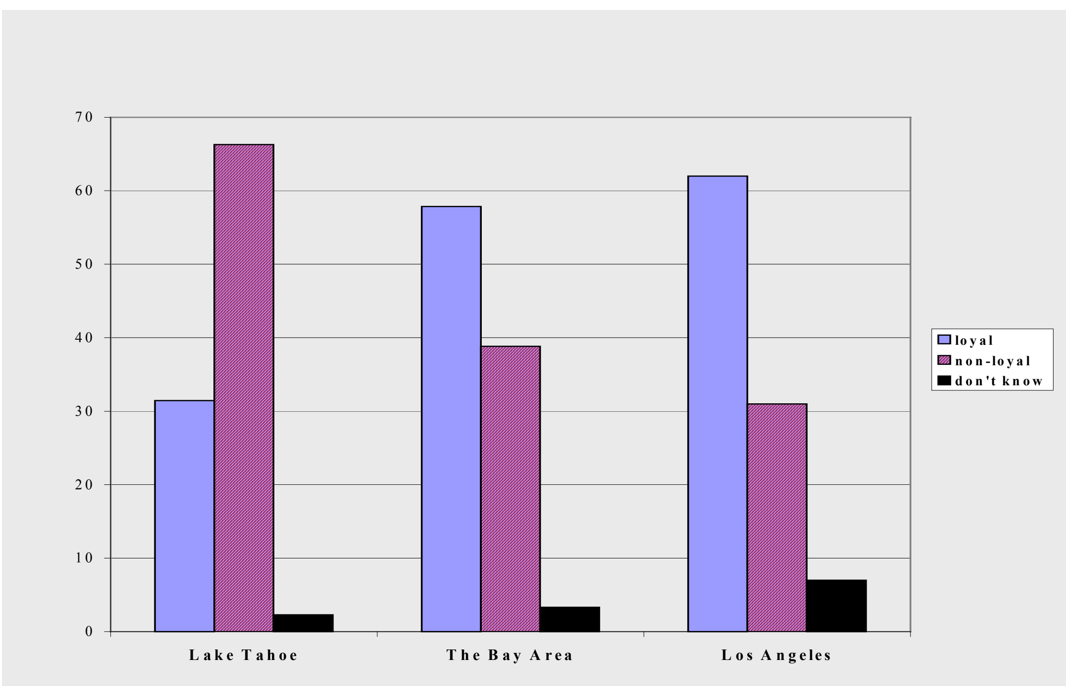
Fuel Type	Defining Oxygenate Concentration (Vol %)		Range of Oxygenate Observed (Vol %)	
	Ethanol	MTBE	Ethanol	MTBE
Non-Oxygenated	< 0.5	≤ 0.6	N/A	N/A
MTBE-Blended	< 0.5	>0.6	N/A	7.68 – 13.59
Ethanol-Blended	≥0.5	≤ 0.6	5.30 - 5.97	N/A

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” customers were assumed to be those customers who answered “no”; “non-loyal” customers were assumed to be those customers who answered “yes”. These data are shown in Figure IV-1 for each of the three regions in the field study.

Figure IV-1:
Regional Percentage of Consumers Using Same Brand of Fuel[1]



[1] Current and previous fuelings.

As can be seen from Figure IV-1, in the Los Angeles and San Francisco Bay areas, 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.

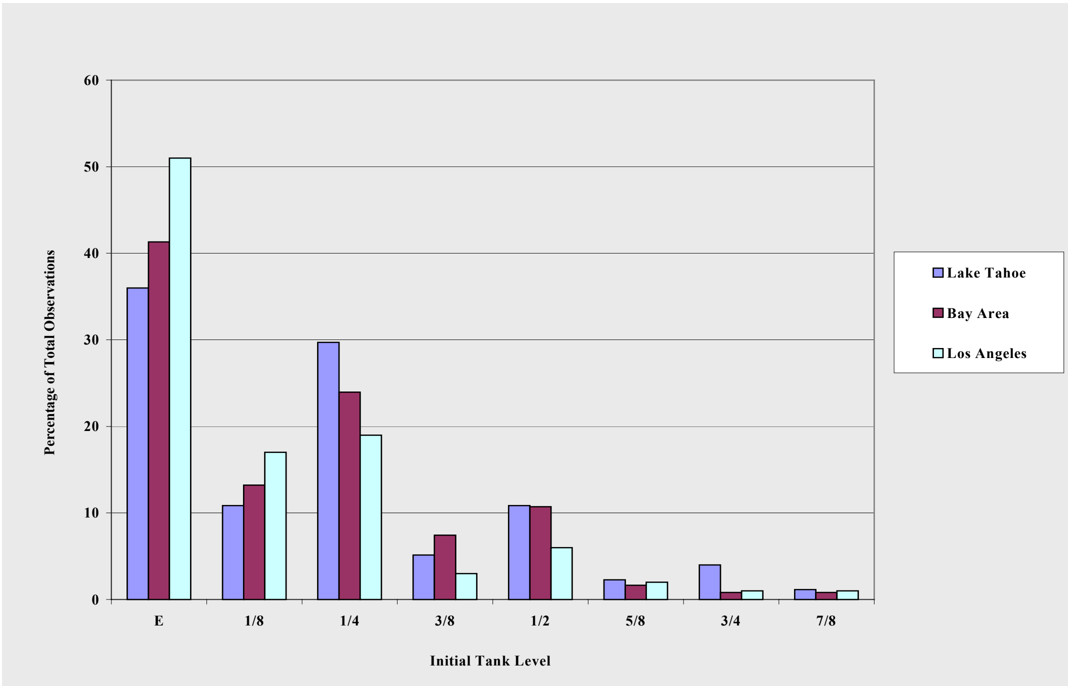
As compared to the Los Angeles and San Francisco Bay areas, the results in the Lake Tahoe area were significantly different. As can be seen in Figure IV-1, in the Lake Tahoe area the percentage of loyal consumers was slightly more than 30 percent, only about half the percentage as in the Los Angeles and San Francisco Bay areas; conversely, the percentage of non-loyal customers 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.

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.

Figure IV-2:
Distribution of Initial Fuel Tank Levels



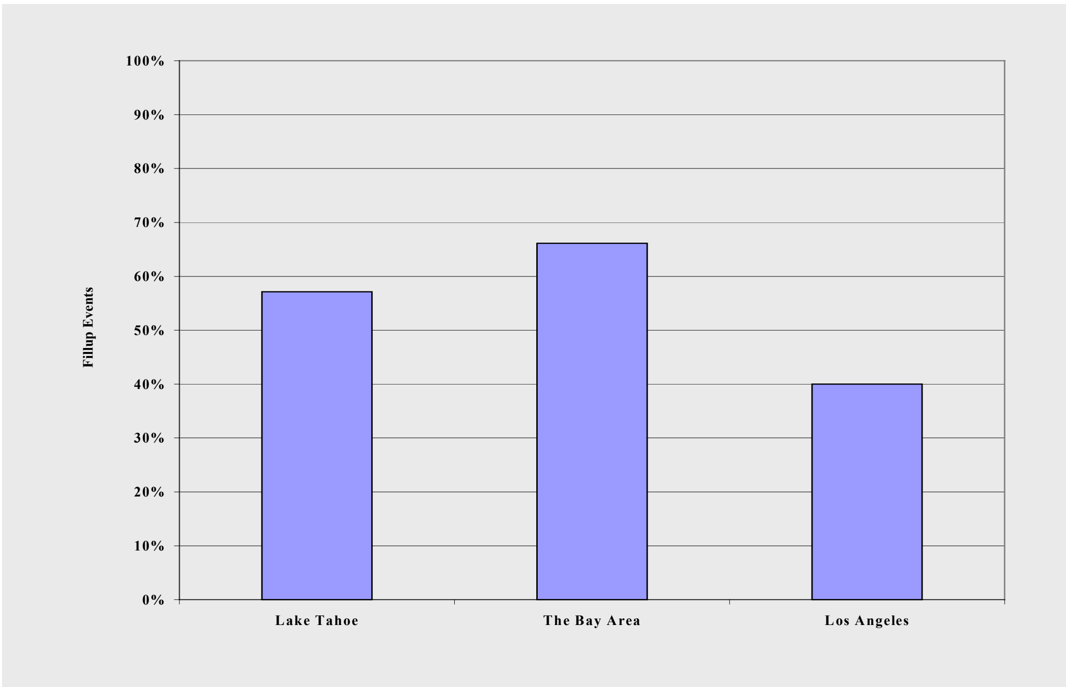
These data are consistent with data taken from a General Motors (GM) fueling survey of over 1100 fuelings[3]. In the GM data, nearly 60 percent of the fuelings occurred with less than 0.2 of the fuel tank capacity remaining, and about 85 percent occurred with less than 0.3 of the fuel tank capacity remaining.

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.

[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.

Figure IV-3:
Percentage of Fillup Fueling Events



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 San Francisco 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	San Francisco Bay	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.

[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.

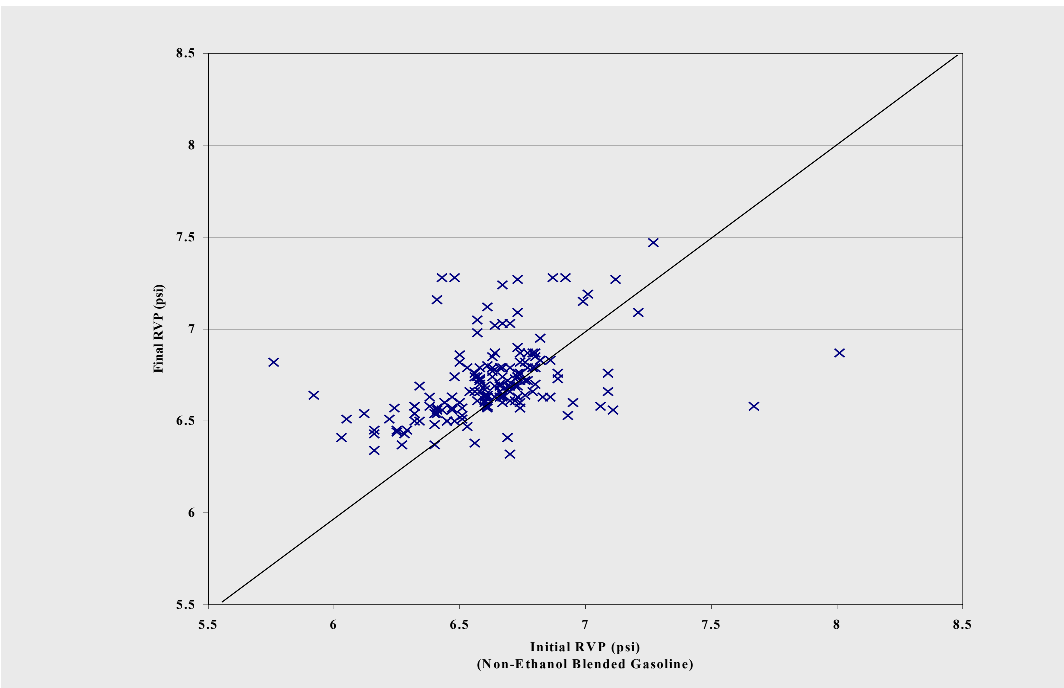
When evaluating the field data based on the above classifications, it is important to note that "non-ethanol blends" refer to either non-oxygenated or MTBE produced gasoline. "Commingled gasoline" refers to gasoline that contains at least 0.5 volume percent ethanol, but less than 5 volume percent ethanol, 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. Currently, nearly 90 percent of gasolines supplied in California are 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

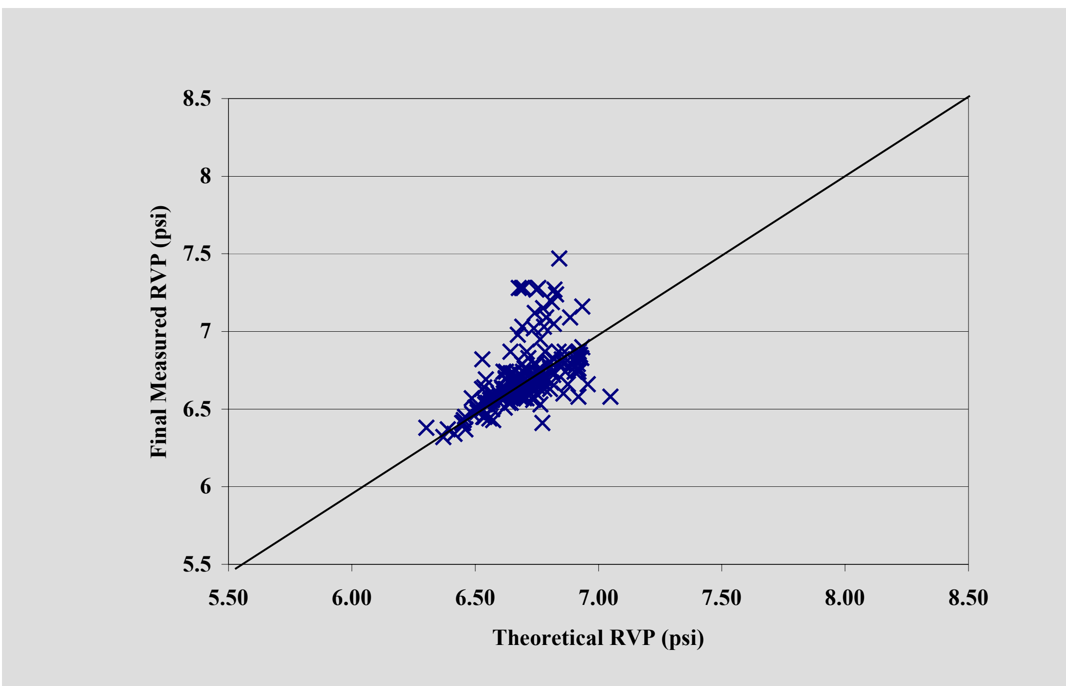


As can be seen in Figure V-1, on average small increases between the initial and final fuel tank RVP were observed in the field study data. The changes that were observed were likely the result of dispensing a higher RVP fuel into a “weathered” fuel in the vehicle fuel tank. Fuel weathering is a result 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]. Using this value 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 Non-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 G.

[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.

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.

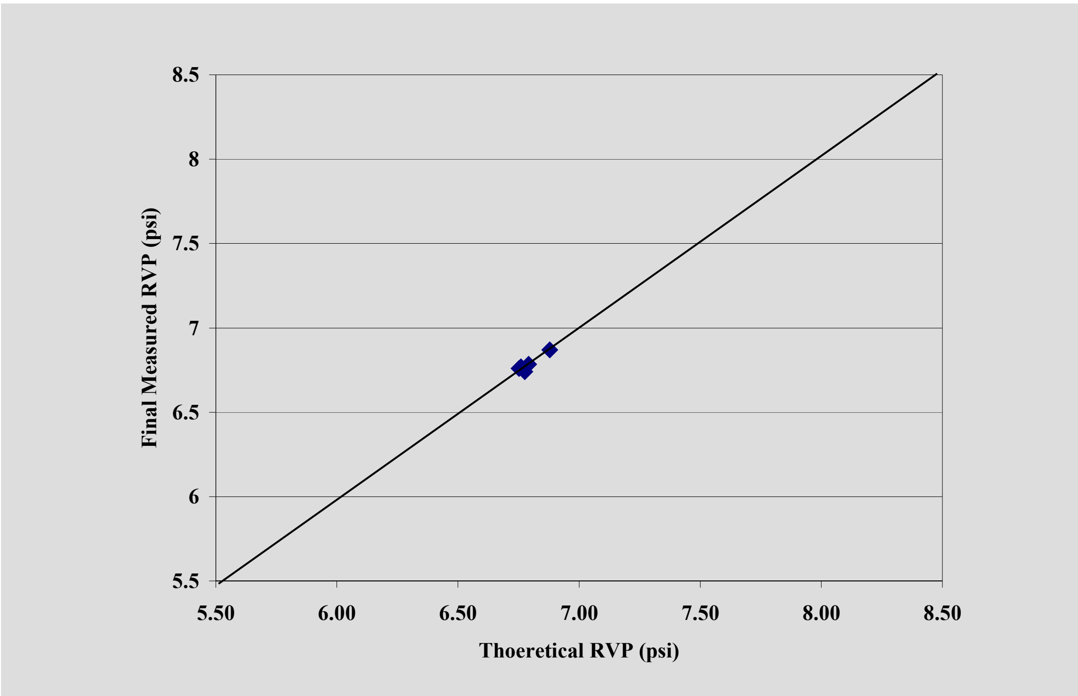
finally, although staff observed 165 fuelings in this category, the average values presented in Table V-1 are based on 160 of those events. Data from five fuelings were not included in this analysis due to the extremely low RVP of the dispensed fuels. The minimum RVP specification incorporated into the 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 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 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

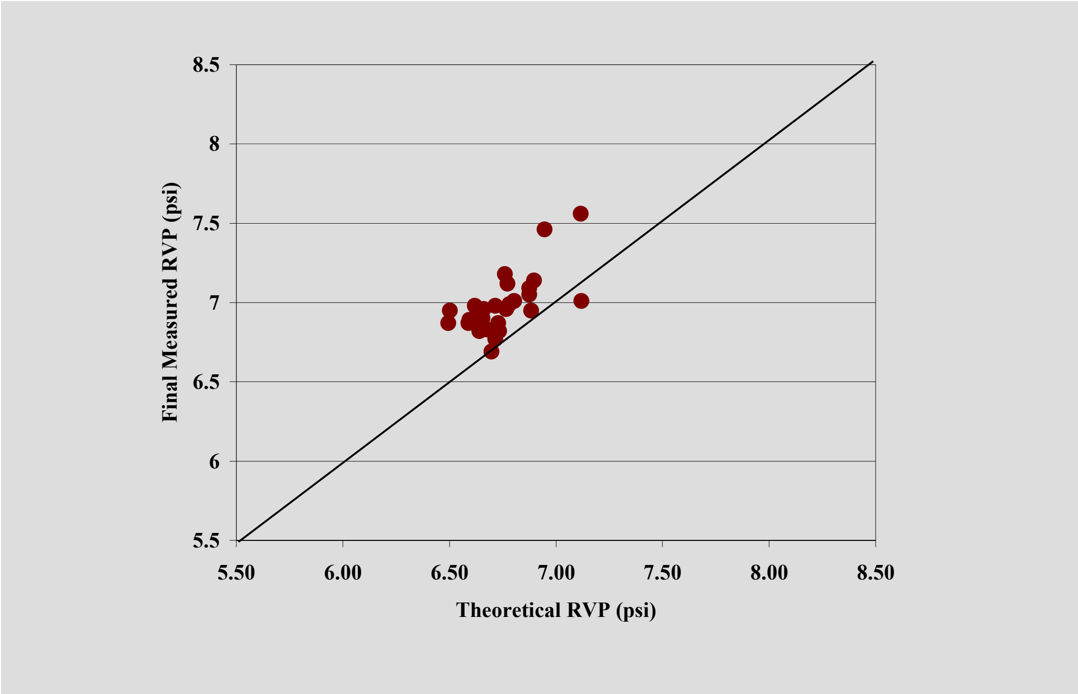
[1]Based on 4 observed fuelings.

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 Gasoline 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

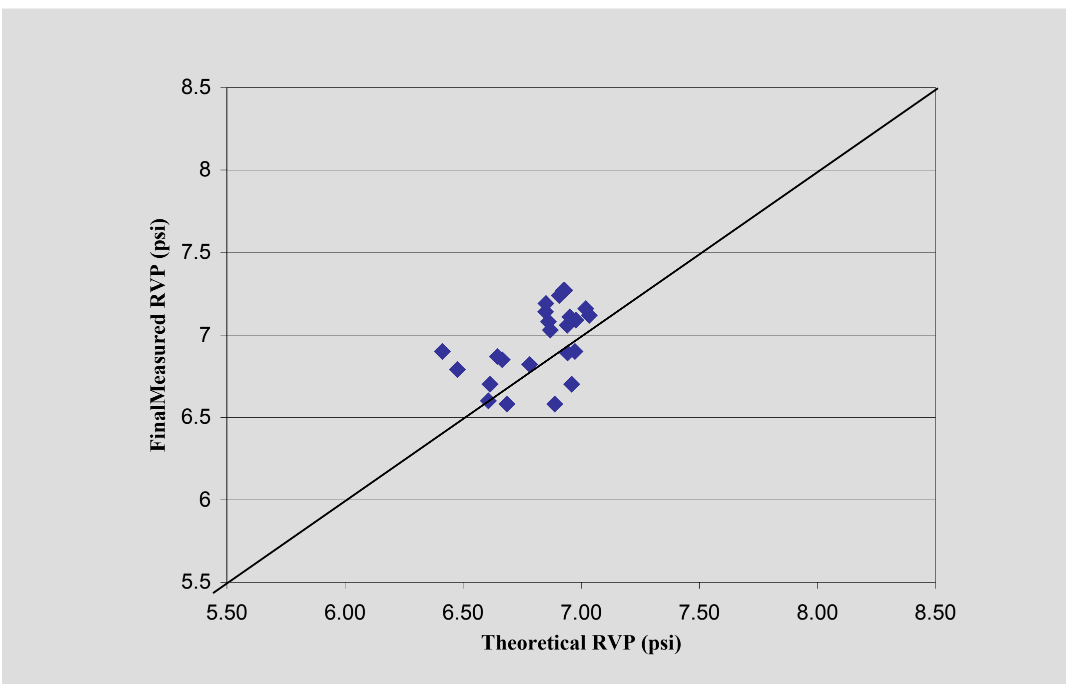
[1]Based on 29 observed fuelings.

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 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.

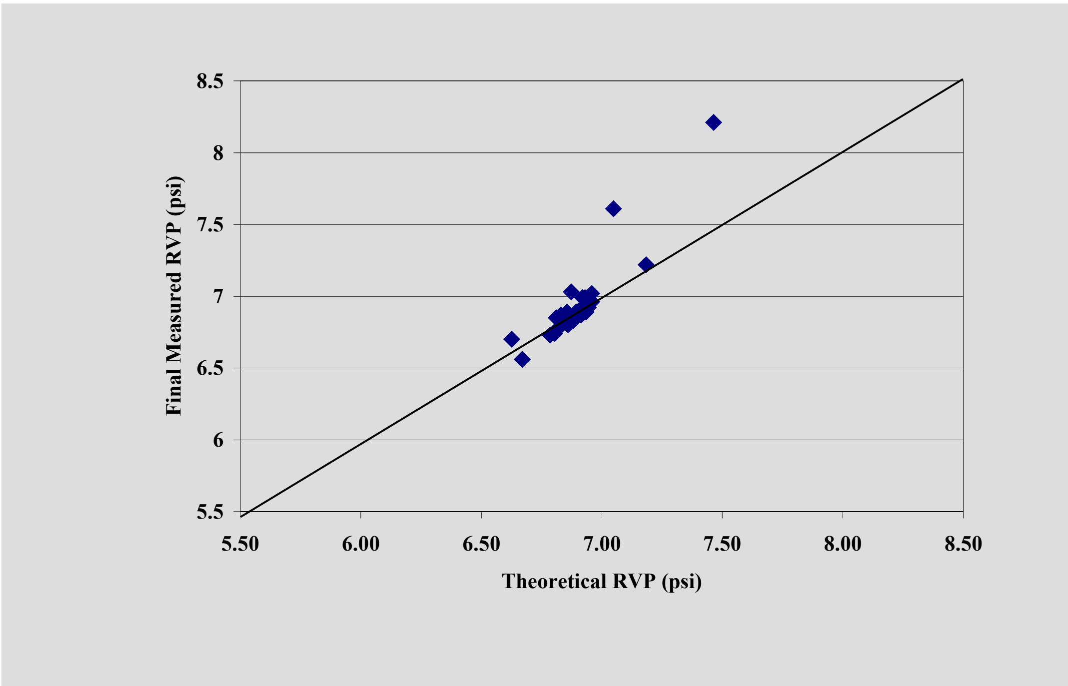
Although staff observed 24 fuelings in this category, the average values presented are based on 21 of those events. Data from three fuelings were not included in this analysis due to the extremely low RVP of the dispensed fuels. The minimum RVP specification incorporated into the Phase II federal RFG 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 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 discussing 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 customer loyalty information collected in each area, as shown in Figure IV-1. In their analysis, staff assumed that brand loyal customers were represented by "Mixing of non-ethanol blended gasolines" and "Mixing of ethanol-blended gasolines", which results in no commingling impacts, and that the remaining four fuel mixing scenarios in Table V-6, apportioned equally, represented non-loyal customers. The potential impacts of each region in the field study are presented in Table V-7. Staff computed each region commingling impacts as the product of average RVP increase of the last four fuel mixing scenarios, as shown in Table V-6 and non-loyal consumers fraction of the corresponding region, as shown in Figure IV-1. The statewide result of staff's evaluation is also presented in Table V-7. To determine the anticipated statewide commingling impact, staff weighted the contribution of each area based on the percentage of the regional gasoline consumption that occurred in each area[6]. This is shown in Table V-8.

[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.

Table V-7:
Anticipated Commingling Impacts Based on Field Study Data

Region	Commingling Impact (ΔRVP, psi)	Weighting Factor by Region
Los Angeles	0.06	0.65
Bay Area	0.07	0.33
Lake Tahoe	0.13	0.02
Statewide Average	0.06	1.0

Table V-8:
1998 Gasoline Consumption by Region[1]

Region	1998 Gasoline Consumption (Thousands of Gallons)	Percent of Regional Gasoline Consumption
Los Angeles	6,074,673	65%
Bay Area	3,101,350	33%
Lake Tahoe	173,999	2%
Total	**9,350,023**	**100%**

[1] Source: California Energy Commission, Fuels Office, http://www.energy.ca.gov/fuels/gasoline_stations/index.html

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 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 led to a fuel's 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 field sample.

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. This formed the guidelines for staff to pursue.

In evaluating commingling impacts, staff began with observations of consumer fueling patterns, as well as RVP changes in fuel tank, 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. In essence, randomness is vital. Only then could staff generalize the results for the entire population on which a valid conclusion of the report was based.

C. Methodology of Simulation Analysis

The field study showed that consumers behave differently across geographic region 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 San Francisco Bay Area or in Lake Tahoe (Table VI-1). 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, non-ethanol and ethanol-blended gasolines, simultaneously. Loyal customers get the same fuel type for every fueling, so the mixing

Table VI-1 Overall Consumers* Fueling Information
By Region
The 2001 ARB Field Study

Variable		Lake Tahoe	SF Bay Area	Los Angeles
Brand Loyalty (%)**	- Y e s	31	58	62
	- N o	67	38	31
	- Don't Know	2	4	7
Ave. Initial Fuel Tank Level (as a fraction of usable tank capacity)		0.24	0.20	0.16
Fillup (%)	- Y e s	57	66	40
	- N o	43	34	60

*Total observations = 393 (Lake Tahoe = 173, SF Bay Area = 120, and Los Angeles = 100).
**Based on consumers that bought the same brand of gasoline as their last purchase.

of non-ethanol and ethanol-blended gasolines, on which the commingling analysis is based, will never 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, non-loyal consumers commingling contribution from each region was weighted by the corresponding proportion of non-loyal consumers and gasoline consumption.

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% to 65% 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 oil 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., a fuel station would carry either "ethanol-blended" or "non-oxygenated" gasoline only). Consequently, grade switching within the same brand would not lead to commingling. This assumption seems reasonable, in part, because most of grade switching is likely within the same 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).

Consumers Purchase Propensity Toward Ethanol Fuel: One of the most difficult tasks in estimating commingling impacts is the consideration staff had to provide in dealing with non-loyal consumers ethanol purchase propensity that defines their likelihood of purchasing ethanol-blended gasoline. In the loyal consumers case, the issue is simple. The consumers are grouped into two extremes: those who always buy ethanol-blended gasoline (100% ethanol purchase propensity) or those who always buy non-ethanol gasoline (0% ethanol purchase propensity), by the virtue of adherence to a fuel brand. The corresponding ethanol market share scenario being analyzed determines the proportions of these subgroups. If ethanol market share were 25% of the total gasoline market pool, for example, loyal consumers belong to the first extreme "always buy ethanol-blended gasoline" would be 25% of the total loyal consumers while the rest would belong to the other extreme "always buy non-ethanol fuel."

Unlike loyal consumers, ethanol purchase propensity for non-loyal consumers could not be observed in the field, nor could it be deduced from the gasoline brands they purchased; there is no other source to consult either. As a result, the model would randomly assign each of the 5,000 non-loyal consumers being simulated with an ethanol purchase propensity value that lies between the two extreme values of loyal consumers, i.e., between 0% and 100%. From the propensity values assigned, a frequency distribution plot reveals the number of non-loyal consumers who fall into that category. Like loyal consumers case, on average, the overall non-loyal consumers purchase propensity value must equal to the corresponding ethanol market share scenario being modeled.

For a given market share, the distribution of non-loyal consumers ethanol purchase propensity was assumed to follow three kinds of beta distributions ($\alpha+\beta$ equal 2, 3, or 5). A distinct feature that distinguishes these distributions is the way propensity values are assigned. If a majority of non-loyal consumers is assigned a similar propensity value, then the frequency distribution plot would shows a spike around that value. This approach leads to higher commingling impacts, and is called a more conservative scenario ($\alpha+\beta=5$). For example, if ethanol market share were 50% and everyone had similar purchase propensity behavior, then for this scenario the non-loyal consumers would be tightly clustered around 50% ethanol purchase propensity mark. These consumers would always be equally likely to go to either non-ethanol or ethanol fuel stations. As a result, the potential commingling impacts for this approach is high since a lot of mixing of the two fuels is expected to take place.

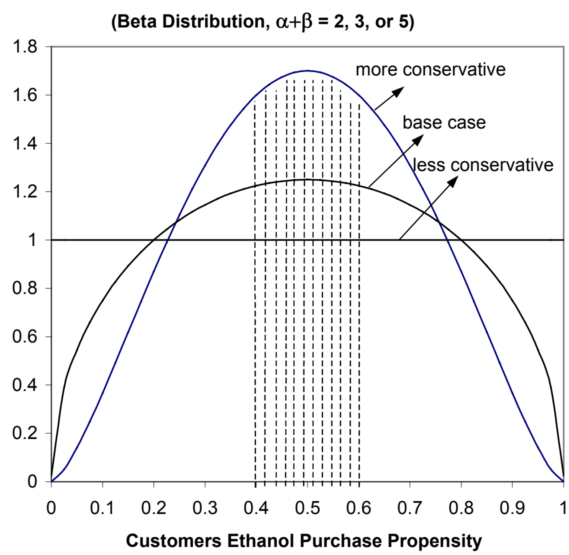
In contrast, a less conservative scenario ($\alpha+\beta=2$) shows a flatter frequency distribution plot since more non-loyal consumers are assigned to other propensity values, say 90 percent and 10 percent, than they would be with a more conservative scenario. Either case would produce lower commingling impacts than the 50 percent propensity case. In this report, base case scenario ($\alpha+\beta=3$) is between the more conservative and less conservative scenarios.

Figure VI-1 graphically illustrates these distributions. A series of beta distribution curves was plotted with a mean at 0.5 that indicates a 50 percent ethanol market share case. The shaded area under each curve represents the proportion of consumers who are assumed to have ethanol purchase propensity between 40 percent and 60 percent. The more conservative scenario assumes 32 percent of consumers fall into this category while the base case and less conservative scenarios assume 24 percent and 20 percent, respectively. Conversely, the last two scenarios show fatter distributions in the tails than the first since more non-loyal consumers fall into 0 percent to 10 percent or 90 percent to100 percent of ethanol purchase propensity ranges.

Fuel Type Switching Patterns: Having assumed the distribution of non-loyal consumers based on their ethanol purchase propensity, the simulation model must generate the non-loyal consumers fuel type switching patterns to produce an estimate of the commingling impacts. This is important because the order in which non-ethanol and ethanol-blended gasolines are used can have a significant effect on the commingling impacts.

For example, consider a 50 percent ethanol purchase propensity case. In this case, non-loyal consumers are equally likely to switch between non-ethanol-blended and ethanol-blended gasolines. For ten fueling events, the consumers would cause maximum commingling impacts if they alternately switching fuel type. If “N” and “E” denote fueling non-ethanol and ethanol-blended gasolines, respectively, NENENENENE or ENENENENEN could represent the above sequence of ten fuelings. All else equal (e.g., remaining fuel in a vehicle fuel tank prior to fueling and amount of fuel dispensed), contrast this with minimal commingling impacts when the first five fuelings are of one type followed by the next five of another type as follows: NNNNNEEEEE or EEEEENNNNN. In the latter case, 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.

Figure VI-1 Customers Ethanol Purchase Propensity Distribution
For 50% Ethanol Market Share



2. Consumer Fueling Habits

Table IV-2 summarizes non-loyal consumer fueling habits by region. These fueling habits are more fully discussed below.

Table VI-2 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

<u>Brand Loyalty</u>: Overall, the percentages of loyal and non-loyal consumer observed do not add up to 100% since a small fraction of participants responded "don't know" when asked whether the current gasoline bought was the same as the last purchase (see Table VI-1). Staff believes this could be the result of several factors, including use of a rental car or a borrowed car from a friend or family member where the driver was unaware of the fueling history. To account for the "don't know" group in the commingling analysis, staff included this group into non-loyal consumers, as shown in Table VI-2. For any given ethanol market share, these figures, along with region gasoline consumption, as shown in Table V-8, were used as weighting factors to estimate statewide commingling impacts.

When the loyalty data in urban areas (58 percent of observed consumers in San Francisco and 62 percent in Los Angeles, as shown in Table VI-1) were compared to the statewide data provided to the staff by gasoline marketers, the field study data were somewhat higher. However, this is not unreasonable given the way the field questionnaire was worded. The loyalty figure from the field survey may include some non-loyal consumers who happened to purchase the same brand twice in a row. They were classified as consumers who "always" buy the same brand by default.

Using data from gasoline marketers, about 40% of California consumers always "use one gasoline brand," more than 50% "use two to three gasoline brands," and the remaining "use many gasoline brands." Rarely, if ever, do consumers make random brand switching. Most of the time, certain 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 loyalty 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. Still, any brand switching in the future may not necessarily cause commingling when both brands are selling the same type of gasoline. It is with this reasoning, staff believes that the field study loyalty data are reasonable.

Initial Fuel Tank Level: According to the field study, the majority of consumers (about 80%) fuel when there is ¼ tank of gasoline or less remaining in their tanks, with more than 40% 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 San Francisco Bay Area or Lake Tahoe, as shown in Table VI-2.

In practice, although fuel gauge may register empty, staff believes that some fuel still remains in the tank. Staff assumed about five percent usable tank capacity for initial fuel tanks recorded as empty ("E") in the field study. The mean tank levels presented in Tables VI-1 and VI-2 were computed based on this assumption. In addition, as described in the previous chapter, staff assumed a five-percent tank "heel," regardless of initial fuel tank levels. This assumption is supported by two sources: Southwest Research Institute and Ford Motor Company data (see Appendix E). As a result, the simulation model also assumes a five-percent or one-gallon tank heel, based on an average 20-gallon usable tank capacity. This 20-gallon usable tank capacity is derived from weighted average usable 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. The U.S. EPA model assumed a ten-percent heel. Staff does not agree with this assumption. A higher heel means more available fuel in the tank to mix with a dispensed fuel. Thus, it leads to higher commingling impacts.

Amount Of Fuel Purchased: As can be seen in Table VI-2, the data collected on non-loyal consumers follow similar fillup trends as the overall consumers observed. 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 simulation analysis. Table VI-3 summarizes the input data and assumptions for the model. The upper portion of the table 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 analysis (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-3 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-oxygenate	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 ($\alpha+\beta$)*		2, 3, or 5	2, 3, or 5	2, 3, 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 (2 = less conservative, 3 = 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 3) is collectively called the base case scenario. Table VI-1 summarizes the results of the base case scenario. Staff believes the base case scenario most likely represents the potential commingling impacts.

The top half 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. For example, if ethanol market share is 25% of total gasoline pool, the average RVP increases due to commingling are estimated to be 0.002 psi, 0.022 psi, and 0.040 psi in Lake Tahoe, SF Bay Area, and Los Angeles, respectively. These figures are calculated from the average RVP increases in each region weighted by the corresponding non-loyal consumer proportions and gasoline consumptions (Appendix N). 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.

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 0.064-0.080 psi RVP for 6 volume percent ethanol blends and 0.071-0.089 psi 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, $\alpha+\beta=3$)
(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	0.022	0.038	0.062
30	6	6.71	5.74	0.003	0.025	0.040	0.068
35	6	6.71	5.74	0.003	0.025	0.046	0.074
40	6	6.71	5.74	0.003	0.026	0.046	0.075
45	6	6.71	5.74	0.003	0.027	0.046	0.076
50	6	6.71	5.74	0.003	0.027	0.047	0.077
55	6	6.71	5.74	0.003	0.027	0.047	0.077
60	6	6.71	5.74	0.003	0.026	0.045	0.074
65	6	6.71	5.74	0.002	0.024	0.041	0.068
25	7.7	6.71	5.74	0.003	0.025	0.043	0.070
30	7.7	6.71	5.74	0.003	0.028	0.045	0.076
35	7.7	6.71	5.74	0.003	0.028	0.052	0.083
40	7.7	6.71	5.74	0.003	0.029	0.051	0.084
45	7.7	6.71	5.74	0.003	0.031	0.052	0.085
50	7.7	6.71	5.74	0.003	0.030	0.053	0.086
55	7.7	6.71	5.74	0.003	0.030	0.052	0.085
60	7.7	6.71	5.74	0.003	0.029	0.050	0.082
65	7.7	6.71	5.74	0.003	0.027	0.045	0.075

*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%-50%.

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, $\alpha+\beta=2$)
(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.

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 produced by California refiners. 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 the average RVP boost from 15,000 consumers with 500 fuel purchases each)
(Draft)

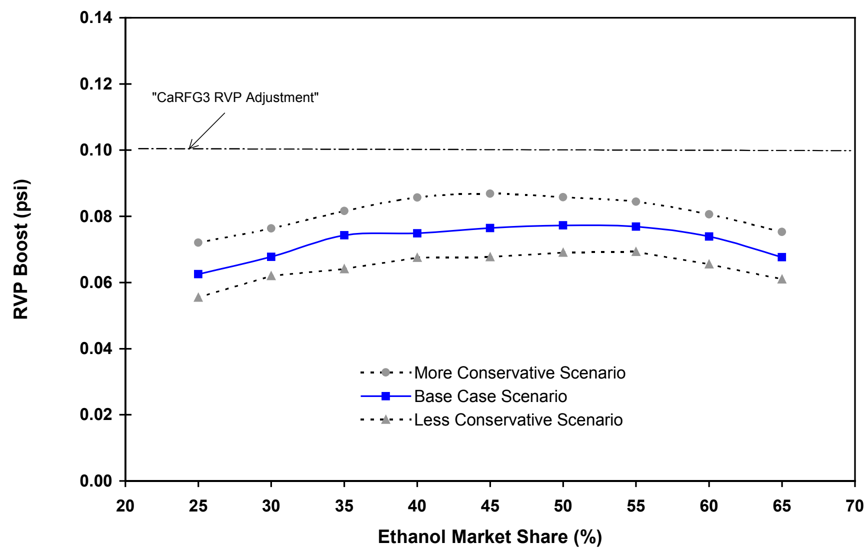
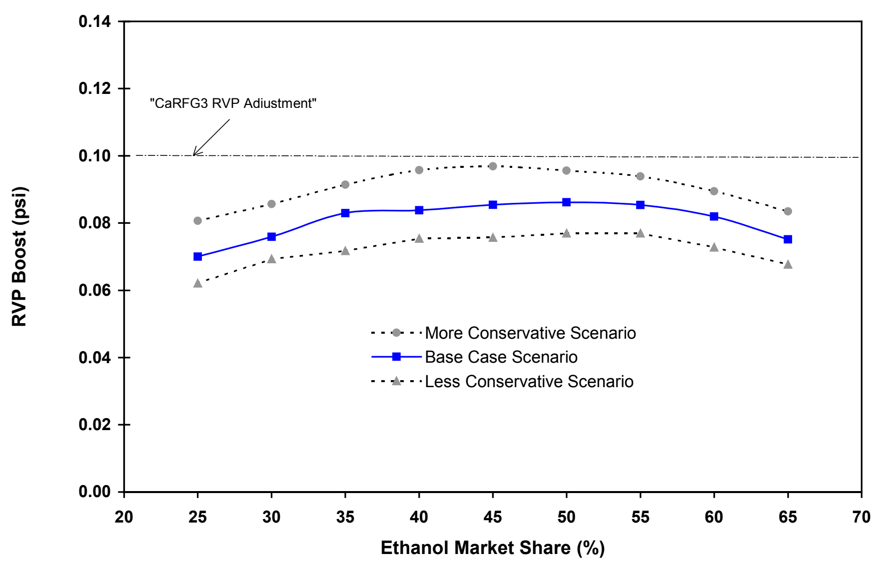


Figure VII-2
Statewide Commingling Impacts Of 7.7 Vol% Ethanol Blend For Various Market Shares
Using The 2001 ARB Field Study Input Parameters
(Each point represents the average RVP boost from 15,000 consumers with 500 fuel purchases each)
(Draft)



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 modeling 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 impacts of CaRFG3 is about 0.1 psi RVP.

E. Other Factors that May Reduce the Commingling Impacts

Staff plans to further refine some of the input parameters and modeling steps to better characterize consumer fueling habits. For example, 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.

A. 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 P.

In its denial, the U.S. EPA stated that it believed there was great uncertainty regarding potential increases in volatile organic compound (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 grater than 0.1 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.

B. Comparison of U.S. EPA and ARB Commingling Evaluations

A distinct difference between the ARB's and US EPA's analysis 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 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 which, 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 judgement 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 0.1-0.3 psi range of RVP increases from commingling in the South Coast air basin, with 0.2 psi RVP picked as the likely commingling impacts (see Appendix P). Given the field observations now available and improved simulation model, staff believes that the U.S. EPA has grossly overestimated the potential commingling impacts by, at least, a factor of two.

[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 O.