Appendix E

Effect of Transitions to Different Ethanol Contents

Transition from Gasoline with One Ethanol Content to Another

A. Introduction

When ethanol is added to gasoline, the Reid vapor pressure of the gasoline is increased and increased evaporative emissions will result. Also, when two CARBOB's designed for different ethanol concentrations are mixed, it becomes very difficult to determine the proper amount of ethanol to be added to the CARBOB mixture.

Changing the amount of ethanol added at a terminal, leads to changes at the service station tanks and in the vehicle tank. The term "transition" refers to this changeover in the distribution system. Table 1 summarizes the possible transitions. Transitions at the terminal tank include changes from one CARBOB to another, from non-oxygenated fuel to CARBOB, and from CARBOB to non-oxygenated fuel. Transitions at the service station tanks and the vehicle tank involve only changes from one fuel to another.

A transition from one CARBOB to another at a terminal tank results in a transition at the service station tank and in the vehicle tank between fuels with different ethanol content. A transition from a CARBOB to non-oxygenated fuel or vice versa at the terminal tank results in a transition in the service station tank and in the vehicle tank between oxygenated and non-oxygenated fuel.

Table 1
Possible Transitions

Possible Transitions at the Terminal	Corresponding Transitions at Service Station or Vehicle Tank
Zero Oxygen RFG to CARBOB	Zero Oxygen RFG to Ethanol fuel
CARBOB to Zero Oxygen RFG	Ethanol fuel to Zero Oxygen RFG
CARBOB (A) to CARBOB (B)	Ethanol fuel (A) to Ethanol fuel (B)

Note: A and B are the ethanol volume concentrations for which the CARBOBs were designed.

A transition at the terminal is complete when the target fuel or CARBOB properties are attained. This process generally requires more than one tank turnover. Therefore, fuels blended during the intermediate stages of the transition will be different from the original target complying fuel. If no adjustments were made, refiners could ship this intermediate product to the service stations for eventual use in the vehicle even though in some cases the blends downstream of the refinery may not meet CaRFG predictive model requirements.

The primary objective of the ARB's analysis was to determine the effect on emissions of a refinery transition from a gasoline with one ethanol content to another with a different ethanol content. The staff analysis also identified transitions where the RVP cap limit could be exceeded.

B. CARBOBs and Fuels Used in the Analysis

Six CaRFG formulations were evaluated in the staff analysis. The starting points and targets for all transitions were complying fuels or CARBOBS that will produce complying fuels after

blending with ethanol at the target concentration. Table 2 lists the CaRFG formulations used in the analysis and as indicated in Table 3, all of the formulations met the CaRFG predictive model requirements.

Table 4 shows a CARBOB for each of the ethanol CaRFG formulations listed in Table 2. For each of the formulations, a CARBOB was obtained by entering the properties of the formulations into the CARBOB model (version dated July 21, 2000) to get the CARBOB properties. Since the fuels at the start and end of the transition were all complying fuels, any increase in emissions during the transition period could only be due to the use of the fuel mixtures from the intermediate stages of the transition.

Properties of the fuel mixtures were calculated for each turnover of the terminal tank, service station tank, and vehicle tank and then evaluated using the CaRFG Predictive Model to determine the effect on emissions of oxides of nitrogen (NOx), total hydrocarbons and carbon monoxide (THC), and potency weighted Toxics (TOX).

Table 2

CaRFG Formulations Used to Evaluate Potential Emissions Increases from Transitions from One Fuel to Another

Fuel Properties	0-OXY CaRFG	5.7 vol% Ethanol FUEL	5.7 vol% Ethanol Fuel (L)	7.7 vol% Ethanol FUEL	7.7 vol% Ethanol Fuel (L)	10 vol% Ethanol FUEL
Aromatics, vol%	25.0	25.1	26.0	25.1	26.9	24.6
Benzene, vol%	0.6	0.76	0.73	0.70	0.77	0.69
Olefins, vol%	6.0	6.0	5.6	4.0	4.2	1.0
Sulfur, ppm	10	20	14.1	14	11.8	5
T50, deg. F	210	214	214	206	211	214
T90, deg. F	305	305	310	310	312	310
Ethanol, vol.%	0.0	5.7	5.7	7.7	7.7	9.6
Oxygen	0.0	2.1	2.1	2.8	2.8	3.5
RVP, psi	6.80	6.83	6.83	7.16	7.02	7.16

Note:

All of the formulations except those designated with (L) are the ones used by ARB in a December 1999 letter to EPA to support California's request of a waiver of the federal RFG year-round oxygen mandate

The formulations designated with (L) are based on those presented in the MathPro analysis of the expected costs to produce Phase 3 gasoline.

Table 3

Expected Change in Emissions Using the CaRFG3 Predictive Model for the CaRFG Formulations Used in the Analysis

Fuel Properties	0-OXY CaRFG	5.7 vol% Ethanol FUEL	5.7 vol% Ethanol Fuel (L)	7.7 vol% Ethanol FUEL	7.7 vol% Ethanol Fuel (L)	10 vol% Ethanol FUEL
NOx	-3.51%	-0.03%	-0.87%	-0.10%	-0.16%	-0.08%
Exhaust THC	-1.02%	-0.40%	-0.67%	-2.88%	-0.80%	-1.08%
Evap. THC	-2.35%	-1.65%	-1.65%	-6.55%	-2.94%	-6.55%
CO (Reactivity weighted)	0%	0%	0%	-0.09%	-0.09%	-0.19%
Total THC + CO	-0.07%	-0.25%	-0.08%	-0.51%	-0.31%	-0.18%
Pot. Wt. Toxics	-4.86%	-0.80%	-0.20%	-4.39%	-0.06%	-5.95%

Table 4

CARBOBs Predicted to Give the Target Fuels After Oxygenation with Ethanol

CARBOB Properties	5.7 vol% Ethanol FUEL	5.7 vol% Ethanol Fuel (L)	7.7 vol% Ethanol FUEL	7.7 vol% Ethanol Fuel (L)	10 vol% Ethanol FUEL
Aromatics, vol%	26.5	27.5	27.0	29.0	27.0
Benzene, vol%	0.80	0.77	0.75	0.83	0.75
Olefins, vol%	6.3	5.9	4.3	4.5	1.0
Sulfur, ppm	20	14	14	12	4
T50, deg. F	217	218	213	217	221
T90, deg. F	307	312	313	315	314
RVP, psi	5.6	5.6	6.0	5.8	6.0

C. Assumptions

1. Emission calculations are based on a four week transition period.

2. The terminal tank heel amount would be the only heel amount varied because that is the only tank turnover that can be practically controlled by the supplier. The terminal tank heel amounts would be 10 percent, 25 percent and 50 percent.

3. The service station tank and vehicle tank would have average heels of 20 percent and 25 percent of capacity, respectively.

4. For terminal tank transitions from one CARBOB to another, the starting fuel and the target fuel for the underground tank transition and the vehicle tank transition would have the same properties as the ethanol fuels for which the starting and target CARBOBs were designed.
5. For terminal tank transitions from a CARBOB to non-oxygenated fuel, the starting fuel for the underground tank transition and the vehicle tank transition would have the same

properties as the ethanol fuel for which the starting CARBOB was designed and the target fuel would have the same properties as the target non-oxygenated fuel at the terminal tank.

6. For terminal tank transitions from non-oxygenated fuel to CARBOB, the starting fuel for the underground tank transitions and the vehicle tank transitions would have the same properties as the starting non-oxygenated fuel at the terminal tank and the target fuels would have the same properties as the ethanol fuels for which the target CARBOBs were designed.

7. For terminal tank transitions from one CARBOB to another, and transitions from non-oxygenated fuel to CARBOB , the CARBOB mixture from each tank turnover would be blended at the terminal with ethanol at the concentration of the target fuel.

8. The calculation of oxygen concentration of the fuels would use the same assumptions as those used in the CARBOB model dated July 21, 2000, namely a fuel density of 0.718 g/cc, ethanol density of 0.794 g/cc, and ethanol purity of 95 percent. For ethanol concentrations of 5.7, 7.7 and 9.6 volume percents, the respective weight percent values for oxygen were 2.1, 2.7 and 3.5.

9. The terminal tank would undergo one turnover per week, the service station tank two turnovers per week and the vehicle tank one turnover per week (Figure E-1). This means that during the four week transition period, the terminal tank would undergo a total of four turnovers, the service station tank a total of eight turnovers, and the vehicle tank a total of four turnovers.

10. In each week of the four-week transition period, half of the vehicles would refuel with the fuel mixture resulting from the first turnover at the service station while the remaining half of the vehicles would refuel with the fuel mixture resulting from the second turnover at the service station (Figure E-1). The calculated change in vehicle emissions would be the average for the two sets of vehicles

D. Properties of Fuel Mixtures

With one exception, a linear model (Equation E-1) was used to calculate the values for properties of the mixtures produced with each turnover. The exception was the calculation of RVP when the turnover involved commingling of non-oxygenated gasoline and ethanol fuel.

The linear model assumes that in a mixture of two CARBOBs, or a mixture of CARBOB and non-oxygenated fuel, each component in the mixture will contribute to the properties of the mixture in proportion to the volume fraction of the individual component in the mixture.

Equation E-1

$$P_{mix} = X P_1 + (1 - X) P_2$$

Where:

P_{mix}	=	Value for the property in the mixture of CARBOBs or fuels
P_1	=	Value of the same property in component #1 before mixing
P_2	=	Value of the same property in component #2 before mixing
X	=	Volume fraction of component #1 in the mixture of components #1 and #2

RVP of Commingled Fuels

Commingling of non-oxygenated CaRFG and ethanol fuel will occur only in the service station underground storage tank and the vehicle tank. For such ethanol gasoline mixtures, all properties except RVP were calculated according to the linear model (Equation E-1). The RVP boost and the RVP of the commingled fuels were calculated using Equations E-2 and E-3, respectively.

Equation E-2

$$\Delta RVP = \left(\frac{1}{1.11} + 1.845516E - 0.76405\,E^2 + 0.837258E^3 \right)^{-1} \left(\frac{1.11 + 0.05(8.4 - B)}{1.11} \right)$$

Equation E-3

$$RVP_{com} = X\,(B + \Delta RVP) + (1 - X)\,RVP_{EtOH}$$

Where:

E	=	Ethanol concentration (percent) of commingled fuel
B	=	Base RVP of non-oxygenated fuel
RVP_{com}	=	RVP of commingled fuels
X	=	Fraction of fuel mixture that is non-oxygenated fuel
RVP_{EtOH}	=	RVP of ethanol fuel in mixture

Equation E-2 was proposed by Rocke (1999). This equation is different from the CARBOB model equation but it applies to the range of ethanol concentrations from 0 to 10 percent whereas the CARBOB model equation does not apply when ethanol concentrations are lower than 4 percent. For ethanol concentration ranges applicable to both the CARBOB and Rocke equations, the estimated RVP values are similar.

E. Estimation of Emission Impacts

When the product of a tank turnover was a mixture of fuels, the properties of the fuel mixture were entered directly into the CaRFG Predictive Model to determine whether the fuel complied with the predictive model standards. When the product of a tank turnover was a CARBOB mixture, the CARBOB model was used to predict the properties of the fuel that would result after blending the CARBOB mixture with the appropriate amount of ethanol. The ethanol concentration entered into the CARBOB model was the target concentration for the transition.

The fuel properties predicted by the CARBOB model were then entered into the CaRFG predictive model for evaluation.

Each terminal tank turnover results in a different fuel blend in the vehicle tank. An example of the transition from one ethanol fuel to another is shown in Figure E-1 (the assumptions used in the analysis were described earlier in Section C). Using the predictive model, the expected change in emissions were determined for each fuel blend obtained with each vehicle tank turnover. An examples of the spreadsheet analysis for one transition is shown in Tables 15 to 18. A complete set of the calculations is available on request (see list of references).

For each terminal tank transition starting with a given heel, there were four emissions values for each vehicle. An average value for the emissions change during each terminal tank transition starting with a given heel was obtained by averaging the eight emissions values for the two vehicles. This change in emissions was also reported as a percentage of RFG2 benefits for that pollutant using Equation E-4.

Equation E-4

$$RFG = \frac{(28 \ x \ EMS \ x \ EXH)}{365 \ x \ Ben} \ x \ 100\%$$

Where:

RFG	=	Change in emissions as a percentage of RFG2 benefits
Ben	=	RFG 2 benefit for pollutant (190 tpd for HC and 110 tpd for NOx)
EMS		Expected percent change in emissions using the CaRFG Predictive Model
EXH		Statewide exhaust emissions for pollutant (tpd) from EMFAC ver. 7G (997 tpd for HC and 1318 tpd for NOx)

F. Results

Tables 5 through 13 summarize the results of the staff analysis. Tables 5 through 7 show the number of tank turnovers at the three locations (terminal, service station, and vehicle) that did not produce a fuel that met the predictive model standards. A value of zero for a transition at a given location (terminal, service station, or vehicle) means that there would be no increase in emissions with any fuel mixture resulting from any of the tank turnovers at that location. The tables also identify the pollutants for which there were emissions increases and the tank turnovers that resulted in RVPs that exceeded the cap limits.

The predictive model estimates the emissions changes which result when a gasoline is consumed in a motor vehicle. So, the emissions results shown in Tables 5 and 6 for the terminal and service station were calculated as if the fuel were directly consumed in a vehicle even though the fuel undergoes further mixing as it passes through the distribution system to the vehicle. The staff analysis assumed that there would be no emissions impact except at the vehicle and consequently any constraints on terminal tank operations would be based on the results for the vehicle tank turnovers.

The predicted changes in exhaust emissions are shown in Tables 8 to 11 for each of the fuel mixtures obtained with the vehicle tank turnovers during the four week transition period. The complete set of emissions data for the target pollutants are reported in Tables 8 to 10. Table 11 shows the emissions results only for those transitions for which there was an increase in emissions with any of the three tank heels considered. The predicted change is reported as an average for the transition period. This average is also expressed as a percent change in RFG Phase 2 benefits as described in Section E.

The staff's analysis showed that the emissions impact of the tank transitions depended on at least three factors:

- the relative amount of the fuel remaining in the terminal tank (the heel) at each tank turnover,
- whether the oxygen content increased or decreased with the transition, and
- the CaRFG properties

The results of the staff analysis are summarized under four types of terminal tank transitions:

- from CARBOB to CARBOB with increasing oxygen content,
- from CARBOB to CARBOB with decreasing oxygen content,
- from non-oxygenated fuel to CARBOB, and
- from CARBOB to non-oxygenated fuel.

Terminal Tank Transitions from CARBOB to CARBOB with increasing oxygen content

These transitions at the terminal result in service station and vehicle tank transitions from an ethanol fuel of one oxygen content to an ethanol fuel with a higher oxygen content. These transitions could increase NOx emissions from the vehicle tailpipe.

The analysis predicts that NOx emissions will increase as the terminal tank heel increases. At the larger tank heels, a larger fraction of the CARBOB mixture will be contributed by the CARBOB designed for a lower ethanol concentration than the concentration at which the mixture will be blended. Therefore, over oxygenation and NOx emissions are expected to be greater at the larger tank heels.

The transition from 5.7 to 7.7 % ethanol with the higher sulfur content fuels was the only transition in this group that resulted in an increase in NOx emissions when the terminal tank heel was 10 percent. However, when the sulfur content of the fuels was decreased, there was no increase in emissions with the transition from 5.7 to 7.7 volume percent ethanol fuel.

The results of the analysis indicate that the adverse emissions impacts can be minimized by controlling the tank heel at each turnover and by changing the properties of the target fuel at the first terminal tank turnover. The staff's analysis shows that emissions increases can be prevented if the following is done:

- the terminal tank heel is not allowed to exceed 10 percent during any of the tank turnovers required to complete the transition, and
- the sulfur content of the target fuel is reduced for at least the first turnover.

Transitions from CARBOB to CARBOB with decreasing oxygen content

This transition at the terminal results in a transition at the service station and vehicle from an ethanol fuel of one oxygen content to an ethanol fuel with a lower oxygen content. These transitions can increase hydrocarbon emissions from the vehicle tailpipe. There was no emissions increase when the terminal tank heel was 10 percent. The analysis predicts that hydrocarbon emissions will increase as the terminal tank heel increases. The staff's analysis shows that emissions increases can be prevented if the following is done:

- the terminal tank heel is not allowed to exceed 10 percent during any of the tank turnovers required to complete the transition, and
- the sulfur content of the target fuel is reduced for at least the first turnover.

Transitions from non-oxygenated fuel to CARBOB

This transition at the terminal results in commingling of non-oxygenated and ethanol fuels in the service station tank and the vehicle tank. The analysis predicts that this commingling will cause an increase in evaporative hydrocarbon emissions and an increase in RVP above the cap limits at all three possible terminal tank transitions and at all three terminal tank heels investigated.

The results of the analysis (Tables 11 and 12) indicate that hydrocarbon emissions and RVP will increase as the terminal tank heel increases. With a larger terminal tank heel, a larger percentage of the fuel blend would be the zero oxygen fuel which has a higher RVP than the CARBOB. Therefore the resulting RVP after blending with alcohol will be higher than the RVP for the smaller terminal tank heel.

Hydrocarbon emissions also increased as the difference in oxygen content between the starting and target fuel increased (Table 11).

Transitions from CARBOB to non-oxygenated fuel

This transition at the terminal also results in commingling of non-oxygenated and ethanol fuels in the service station tank and the vehicle tank. The analysis predicts that for all three possible terminal tank transitions and for all three terminal tank heels investigated, there would be an increase in evaporative hydrocarbon emissions at the vehicle and an increase in RVP above the cap limits at the service station and the vehicle.

The analysis predicts that hydrocarbon emissions and RVP will decrease as the terminal tank heel increases. As the terminal tank heel increases, a larger percentage of the RVP of the fuel mixture is contributed by the CARBOB which has a lower RVP than the non-oxygenated fuel. Consequently, the RVP increase with commingling at the station will be smaller as the terminal tank heel increases. Since the first fuelling of the vehicle will involve mixing of ethanol fuels, there is no RVP boost and the RVP of the mixture is a linear blend of the RVPs of the two fuels. As a result, the RVP shows the same trend at the terminal and the station.

Hydrocarbon emissions increased as the difference in oxygen content between the starting and target fuel increased (Table 11). For example, for a 10 percent terminal tank heel, the hydrocarbon emissions were expected to increase by 0.85 percent for the transition from 5.7% ethanol to zero oxygen fuel. However, the emissions were expected to increase by 0.95 percent

for the transition from 7.7 percent ethanol and by 1.15 percent for the transition from 10 percent ethanol.

RVP Effects

Tables 12 and 13 report the RVP values at all locations during any week that the RVP cap limits were exceeded. These tables may be compared with Tables 5 to 7 which show the number of tank turnovers where the RVP exceeded the cap limits.

The RVP results for the transitions between zero oxygen fuel and the 7.7 and 10 percent ethanol fuels were combined (Tables 12 and 13) because the RVP results were nearly identical. The two ethanol fuels had the same RVP (7.16 psi) The ethanol concentrations in the blended fuels were different for the two transitions but the commingling effect was nearly identical and since the blending ratios were the same at the service station tank and the vehicle, the calculated RVPs for the two transitions were identical.

Tables 12 and 13 also show the number of weeks that the RVP cap limit was exceeded. The RVP effect was present only in the first week for the transition from oxygenated to non-oxygenated fuels. For the transition from non-oxygenated to oxygenated fuels, the change in ethanol content and the magnitude of the terminal tank heel determined the length of the period during which the RVP cap limit was exceeded. This period increased as the difference in ethanol content increased and as the magnitude of the terminal tank heel increased.

Summary

The staff's findings are summarized in Table 14. Transitions from a fuel designed for one level of ethanol to a fuel designed for a different level of ethanol are not expected to increase emissions when:

1. the ratio of the "remaining" fuel to the "added" fuel is 1 to 9 or less, and
2. the added fuel contains no more than 12 ppm sulfur for the first turnover of the transition, and
3. the change in ethanol content is less than 3 percent.

Any other transition is expected to result in an increase in emissions. The staff analysis suggests that the mixing of oxygenated and non-oxygenate blends would result in the RVP cap being exceeded..

G. Octane Considerations

The staff's analysis was concerned only with RVP and emissions increases but refiners must also consider octane levels during transitions that decreases ethanol levels or during transitions to non-oxygenated fuel. One method of ensuring adequate octane would be to blend the CARBOB to full octane strength. Other procedures proposed by the refiners could increase RVP and tailpipe emissions of hydrocarbons because they add more oxygenate to the CARBOB than the concentration for which it was designed. Staff did not consider the effect this over-oxygenation but it is expected to worsen the problems already identified in the staff analysis.

Table 5

Number of Terminal Tank Turnovers that Would not Comply Based on Use of the Predictive Model

Transition from:	Terminal Heel Amount					
	10%		25%		50%	
0 to 5.7 vol%	HC 1		HC 1		HC >4	RVP 2
0 to 7.7 vol%	HC 1	RVP 1	HC 1	RVP 1	HC 3	RVP >4
0 to 10 vol%	NOx 1	RVP 1	HC 1	RVP 2	NOx 3	RVP >4
					HC 1	
5.7 to 7.7 vol% (H)	NOx 1		NOx 1		NOx 3	
5.7 to 7.7 vol% (L)	0		0		NOx 1	
5.7 to 10 vol%	NOx 1		NOx 2		NOx >4	
7.7 to 10 vol%	NOx 1		NOx 1		NOx >4	
7.7 to 5.7 vol% (H)	0		0		HC 1	
7.7 to 5.7 vol% (L)	HC 1		HC 1		HC >4	
10 to 5.7 vol%	0		HC 1		HC 3	
10 to 7.7 vol%	0		0		HC 1	
5.7 to 0 vol%	0		0		0	RVP 1*
7.7 to 0 vol%	0		0		0	RVP 1*
10 to 0 vol%	0		0		0	RVP 1*

Note:
H refers to 5.7 and 7.7 vol% ethanol fuels with 20 and 14 ppmw sulfur, respectively
L refers to 5.7 and 7.7 vol% ethanol fuels with 14 and 12 ppmw sulfur, respectively
* RVP lower than 6.4 psi

Table 6
Number of Gasoline Station Tank Turnovers that Would not Comply
Based on Use of the Predictive Model

Transition from:	Terminal Heel Amount					
	10%		25%		50%	
0 to 5.7 vol%	HC 2		HC 3	RVP 1	HC 7	RVP 2
0 to 7.7 vol%	HC 2	RVP 2	HC 3	RVP 3	HC 6	RVP 8
0 to 10 vol%	HC 2	RVP 2	HC 2	RVP 4	NOx 6 HC 3	RVP 8
5.7 to 7.7 vol% (H)	NOx 2		NOx 3		NOx 6	
5.7 to 7.7 vol% (L)	0		0		NOx 2	
5.7 to 10 vol%	NOx 1		NOx 4		NOx >8	
7.7 to 10 vol%	NOx 1		NOx 3		NOx 6	
7.7 to 5.7 vol% (H)	0		0		HC 3	
7.7 to 5.7 vol% (L)	HC 1		HC 3		HC 7	
10 to 5.7 vol%	HC 1		HC 2		HC 6	
10 to 7.7 vol%	0		HC 1		HC 3	
5.7 to 0 vol%	HC 2	RVP 1	HC 1	RVP 1	HC 1	RVP 1
7.7 to 0 vol%	HC 3	RVP 1	HC 2	RVP 1	HC 1	RVP 1
10 to 0 vol%	HC 3	RVP 1	HC 3	RVP 1	HC 2	RVP 1

Note:
H refers to 5.7 and 7.7 vol% ethanol fuels with 20 and 14 ppmw sulfur, respectively
L refers to 5.7 and 7.7 vol% ethanol fuels with 14 and 12 ppmw sulfur, respectively

Table 7

Number of Vehicle Tank Turnovers that Would not Comply Based on Use of the Predictive Model

Transition from:	Terminal Heel Amount					
	10%		25%		50%	
0 to 5.7 vol%	HC 2	RVP 1	HC 3 (2)	RVP 1 (0)	HC >4	RVP 2
0 to 7.7 vol%	HC 2	RVP 2	HC 2	RVP 3	HC 3	RVP >4
0 to 10 vol%	HC 3	RVP 2	HC 3	RVP 3	HC >4	RVP >4
5.7 to 7.7 vol% (H)	NOx 2		NOx 2		NOx >4	
5.7 to 7.7 vol% (L)	0		NOx 1		NOx 1	
5.7 to 10 vol%	0		NOx 2		NOx >4	
7.7 to 10 vol%	0		NOx 2		NOx 4	
7.7 to 5.7 vol% (H)	0		0		HC 1	
7.7 to 5.7 vol% (L)	HC 1 (0)		HC 2		HC 4	
10 to 5.7 vol%	0		HC 1 (2)		HC 3	
10 to 7.7 vol%	0		0		HC 2	
5.7 to 0 vol%	HC 3 (2)	RVP 1 (0)	HC 2 (0)	RVP 1	HC 1 (0)	
7.7 to 0 vol%	HC 3 (2)	RVP 1	HC 3 (1)	RVP 1	HC 2 (0)	RVP 1
10 to 0 vol%	HC 3 (2)	RVP 1	HC 3 (1)	RVP 1	HC 2 (1)	RVP 1

Note:
H refers to 5.7 and 7.7 vol% ethanol fuels with 20 and 14 ppmw sulfur, respectively
L refers to 5.7 and 7.7 vol% ethanol fuels with 14 and 12 ppmw sulfur, respectively
The number in parentheses applies only when the number of tank turnovers that would not comply is different for the second vehicle than it is for the first vehicle.

Table 8
Predicted Percent Change in Total Hydrocarbon Emissions for Fuel Mixtures in Vehicle Tank

Transition from:	Terminal Tank Heel	Vehicle 1 Predicted change for each turnover				Vehicle 2 Predicted change for each turnover				Average Change During Transition
0 to 5.7 vol%	10%	3.79	0.55	-0.14	-0.32	2.63	0.26	-0.22	-0.35	0.78%
	25%	4.45	1.01	0.05	-0.25	3.38	0.66	-0.06	-0.29	1.12%
	50%	5.63	2.23	0.88	0.23	4.74	1.86	0.70	0.14	2.05%
0 to 7.7 vol%	10%	4.18	0.74	-0.29	-0.46	3.06	0.08	-0.37	-0.48	0.81%
	25%	4.69	1.11	-0.13	-0.40	3.65	0.41	-0.23	-0.43	1.08%
	50%	5.58	2.08	0.56	0.01	4.69	1.36	0.40	-0.07	1.83%
0 to 10 vol%	10%	4.70	1.08	0.22	0.01	3.10	0.70	0.12	-0.02	1.24%
	25%	4.79	1.06	0.19	-0.01	3.18	0.66	0.09	-0.03	1.24%
	50%	5.07	1.19	0.16	-0.07	3.50	0.75	0.05	-0.09	1.32%
5.7 to 7.7 vol% (H) (Sulfur 20 to 14)	10%	-0.83	-0.76	-0.60	-0.54	-1.08	-0.69	-0.57	-0.53	-0.70%
	25%	-0.98	-0.90	-0.68	-0.56	-1.26	-0.82	-0.62	-0.55	-0.80%
	50%	-1.20	-1.23	-0.94	-0.74	-1.55	-1.16	-0.88	-0.71	-1.05%
5.7 to 7.7 vol% (L) (Sulfur 14 to 12)	10%	-0.54	-0.61	-0.49	-0.47	-0.82	-0.57	-0.49	-0.47	-0.56%
	25%	-0.66	-0.72	-0.55	-0.49	-0.97	-0.67	-0.53	-0.48	-0.63%
	50%	-0.86	-0.98	-0.77	-0.62	-1.22	-0.93	-0.72	-0.60	-0.84%
5.7 to 10 vol%	10%	-0.61	-0.32	-0.13	-0.08	-0.61	-0.26	-0.12	-0.08	-0.28%
	25%	-1.03	-0.69	-0.33	-0.15	-1.11	-0.60	-0.26	-0.13	-0.54%
	50%	-1.71	-1.57	-1.02	-0.58	-1.93	-1.49	-0.91	-0.52	-1.22%
7.7 to 10 vol%	10%	-0.60	-0.30	-0.16	-0.08	-0.57	-0.24	-0.11	-0.08	-0.27%
	25%	-0.93	-0.61	-0.28	-0.14	-0.98	-0.53	-0.24	-0.12	-0.48%
	50%	-1.45	-1.31	-0.86	-0.51	-1.60	-1.25	-0.78	-0.46	-1.03%
7.7 to 5.7 vol% (L) (Sulfur 12 to 14)	10%	-0.27	0.12	0.03	0.00	-0.19	0.08	0.02	0.00	-0.03%
	25%	-0.14	0.23	0.09	0.02	-0.03	0.18	0.06	0.01	0.05%
	50%	0.09	0.50	0.30	0.14	0.24	0.45	0.24	0.12	0.26%
7.7 to 5.7 vol% (H) (Sulfur 14 to 20)	10%	-0.59	-0.25	-0.38	-0.38	-0.54	-0.29	-0.36	-0.38	-0.40%
	25%	-0.42	-0.13	-0.31	-0.36	-0.34	-0.18	-0.32	-0.36	-0.30%
	50%	-0.13	0.19	-0.10	-0.22	0.00	0.13	-0.11	-0.24	-0.06%
10 to 5.7 vol%	10%	-0.32	-0.37	-0.27	-0.36	-0.18	-0.08	-0.31	-0.37	-0.24%
	25%	0.05	-0.07	-0.11	-0.30	0.26	0.19	-0.19	-0.33	-0.06%
	50%	0.68	0.66	0.38	0.03	1.00	0.92	0.31	-0.03	0.49%
10 to 7.7 vol%	10%	-0.35	-0.27	-0.44	-0.50	-0.40	-0.34	-0.47	-0.51	-0.41%
	25%	-0.15	-0.11	-0.40	-0.47	-0.15	-0.20	-0.41	-0.49	-0.30%
	50%	0.21	0.30	-0.09	-0.30	0.27	0.21	-0.14	-0.33	0.02%
5.7 to 0 vol%	10%	5.07	1.17	0.22	0.00	0.40	0.02	-0.05	-0.07	0.85%
	25%	4.39	0.70	0.01	-0.08	-0.24	-0.38	-0.23	-0.13	0.51%
	50%	3.35	-0.36	-0.79	-0.59	-1.17	-1.37	-0.96	-0.59	-0.31%
7.7 to 0 vol%	10%	5.53	1.25	0.24	0.00	0.59	0.07	-0.04	-0.06	0.95%
	25%	5.03	0.91	0.09	-0.05	0.11	-0.22	-0.17	-0.11	-0.70%
	50%	4.23	0.11	-0.50	-0.42	-0.62	-0.97	-0.70	-0.44	0.09%
10 to 0 vol%	10%	6.16	1.46	0.30	0.02	1.09	0.22	0.00	-0.06	1.15%
	25%	5.86	1.27	0.21	-0.01	0.86	0.06	-0.07	-0.08	1.01%
	50%	5.42	0.88	-0.08	-0.21	0.55	-0.27	-0.34	-0.25	0.71%

Table 9
Predicted Percent Change in NOx Emissions for Fuel Mixtures in Vehicle Tank

Transition from:	Terminal Tank Heel	Vehicle 1 Predicted change for each turnover				Vehicle 2 Predicted change for each turnover				Average Change During Transition
0 to 5.7 vol%	10%	-2.04	-0.29	-0.11	-0.07	-1.55	-0.22	-0.09	-0.06	-0.55%
	25%	-2.22	-0.43	-0.18	-0.09	-1.75	-0.35	-0.15	-0.08	-0.66%
	50%	-2.50	-0.78	-0.45	-0.26	-2.10	-0.70	-0.40	-0.23	-0.93%
0 to 7.7 vol%	10%	-2.38	-0.66	-0.08	-0.08	-1.79	-0.08	-0.08	-0.08	-0.65%
	25%	-2.40	-0.67	-0.08	-0.08	-1.81	-0.08	-0.09	-0.08	-0.66%
	50%	-2.44	-0.69	-0.10	-0.09	-1.85	-0.10	-0.10	-0.09	-0.68%
0 to 10 vol%	10%	-3.23	-1.15	-0.45	-0.27	-2.38	-0.84	-0.37	-0.25	-1.12%
	25%	-3.02	-0.95	-0.36	-0.23	-2.11	-0.67	-0.30	-0.22	-0.98%
	50%	-2.66	-0.48	0.00	-0.01	-1.67	-0.19	0.05	-0.02	-0.62%
5.7 to 7.7 vol% (H) (Sulfur 20 to 14)	10%	0.17	0.17	-0.07	-0.07	0.54	0.09	-0.04	-0.07	0.09%
	25%	0.32	0.29	-0.04	-0.04	0.72	0.21	0.01	-0.05	0.18%
	50%	0.57	0.61	0.24	0.10	1.03	0.52	0.23	0.08	0.42%
5.7 to 7.7 vol% (L) (Sulfur 14 to 12)	10%	-0.35	-0.08	-0.14	-0.19	0.10	-0.11	-0.17	-0.19	-0.14%
	25%	-0.28	-0.02	-0.13	-0.18	0.19	-0.06	-0.15	-0.18	-0.10%
	50%	-0.17	0.13	-0.07	-0.11	0.33	0.09	-0.05	-0.12	0.00%
5.7 to 10 vol%	10%	-0.12	-0.14	-0.13	-0.20	-0.06	-0.15	-0.19	-0.20	-0.15%
	25%	0.26	0.19	-0.06	-0.14	0.40	0.15	-0.06	-0.16	0.07%
	50%	0.91	0.99	0.54	0.23	1.19	0.96	0.50	0.18	0.69%
7.7 to 10 vol%	10%	0.03	-0.10	-0.26	-0.20	0.03	-0.13	-0.18	-0.20	-0.13%
	25%	0.27	0.10	-0.05	-0.16	0.31	0.06	-0.11	-0.17	0.03%
	50%	0.67	0.59	0.28	0.07	0.79	0.55	0.24	0.03	0.40%
7.7 to 5.7 vol% (L) (Sulfur 12 to 14)	10%	-0.63	-1.15	-1.06	-1.04	-0.74	-1.11	-1.05	-1.04	-0.98%
	25%	-0.70	-1.20	-1.07	-1.05	-0.82	-1.16	-1.08	-1.05	-1.02%
	50%	-0.81	-1.34	-1.12	-1.11	-0.96	-1.30	-1.17	-1.10	-1.11%
7.7 to 5.7 vol% (H) (Sulfur 14 to 20)	10%	-0.05	-0.30	-0.20	-0.07	-0.07	-0.22	-0.09	-0.06	-0.13%
	25%	-0.20	-0.42	-0.22	-0.09	-0.25	-0.34	-0.14	-0.08	-0.22%
	50%	-0.46	-0.74	-0.49	-0.24	-0.56	-0.65	-0.37	-0.21	-0.47%
10 to 5.7 vol%	10%	-0.38	-0.21	-0.24	-0.09	-0.56	-0.50	-0.17	-0.08	-0.33%
	25%	-0.78	-0.55	-0.32	-0.16	-1.04	-0.81	-0.30	-0.13	-0.51%
	50%	-1.45	-1.38	-1.09	-0.55	-1.84	-1.64	-0.89	-0.48	-1.17%
10 to 7.7 vol%	10%	-0.22	-0.47	-0.15	-0.11	-0.19	-0.36	-0.16	-0.10	-0.22%
	25%	-0.46	-0.68	-0.36	-0.15	-0.49	-0.54	-0.24	-0.13	-0.38%
	50%	-0.87	-1.18	-0.69	-0.39	-0.97	-1.05	-0.59	-0.34	-0.76%
5.7 to 0 vol%	10%	-2.49	-3.23	-3.43	-3.49	-2.80	-3.31	-3.46	-3.50	-3.21%
	25%	-2.30	-3.07	-3.36	-3.46	-2.57	-3.17	-3.40	-3.47	-3.10%
	50%	-1.99	-2.68	-3.06	-3.28	-2.20	-2.78	-3.12	-3.31	-2.80%
7.7 to 0 vol%	10%	-3.06	-3.46	-3.50	-3.51	-3.31	-3.48	-3.50	-3.51	-3.42%
	25%	-3.03	-3.43	-3.46	-3.50	-3.27	-3.45	-3.49	-3.50	-3.39%
	50%	-2.98	-3.36	-3.42	-3.46	-3.20	-3.37	-3.44	-3.47	-3.34%
10 to 0 vol%	10%	-3.98	-3.84	-3.60	-3.53	-4.13	-3.74	-3.57	-3.52	-3.74%
	25%	-4.21	-4.02	-3.69	-3.57	-4.40	-3.91	-3.64	-3.55	-3.87%
	50%	-4.59	-4.48	-4.03	-3.78	-4.85	-4.37	-3.96	-3.74	-4.23%

Table 10
Predicted Percent Change in Toxic Emissions for Fuel Mixtures in Vehicle Tank

Transition from:	Terminal Tank Heel	Vehicle 1 Predicted change for each turnover				Vehicle 2 Predicted change for each turnover				Average Change During Transition
0 to 5.7 vol%	10%	-1.91	-1.46	-1.09	-0.99	-1.82	-1.31	-1.05	-0.97	-1.33%
	25%	-2.49	-1.92	-1.31	-1.07	-2.50	-1.74	-1.23	-1.04	-1.66%
	50%	-3.47	-3.07	-2.17	-1.60	-3.66	-2.89	-2.03	-1.51	-2.55%
0 to 7.7 vol%	10%	-4.06	-4.50	-4.52	-4.49	-4.34	-4.59	-4.51	.4.49	-4.43%
	25%	-4.47	-4.83	-4.68	-4.55	-4.83	-4.89	-4.64	-4.53	-4.68%
	50%	-5.18	-5.67	-5.30	-4.93	-5.67	-5.73	-5.22	-4.88	-5.32%
0 to 10 vol%	10%	-5.19	-5.98	-6.04	-6.04	-5.71	-6.03	-6.04	-6.03	-5.88%
	25%	-5.75	-6.46	-6.27	-6.12	-6.38	-6.47	-6.23	-6.10	-6.22%
	50%	-6.68	-7.61	-7.15	-6.68	-7.49	-7.63	-7.05	-6.60	-7.11%
5.7 to 7.7 vol% (H) (Sulfur 20 to 14)	10%	-3.02	-4.09	-4.44	-4.45	-3.48	-4.21	-4.41	-4.46	-4.07%
	25%	-2.85	-3.94	-4.42	-4.43	-3.28	-4.08	-4.35	-4.44	-3.97%
	50%	-2.56	-3.59	-4.06	-4.26	-2.94	-3.73	-4.11	-4.29	-3.69%
5.7 to 7.7 vol% (L) (Sulfur 14 to 12)	10%	-0.45	-0.33	-0.22	-0.20	-0.50	-0.30	-0.17	-0.20	-0.30%
	25%	-0.63	-0.44	-0.24	-0.22	-0.72	-0.39	-0.21	-0.22	-0.38%
	50%	-0.94	-0.83	-0.61	-0.35	-1.09	-0.78	-0.49	-0.32	-0.68%
5.7 to 10 vol%	10%	-4.03	-5.49	-5.89	-6.00	-4.60	-5.66	-5.94	-6.01	-5.45%
	25%	-3.90	-5.39	-5.90	-5.98	-4.45	-5.57	-5.90	-5.99	-5.39%
	50%	-3.68	-5.13	-5.61	-5.86	-4.19	-5.31	-5.72	-5.89	-5.17%
7.7 to 10 vol%	10%	-5.53	-5.93	-5.96	-6.03	-5.73	-5.97	-6.02	-6.03	-5.90%
	25%	-5.64	-6.02	-5.99	-6.04	-5.86	-6.06	-6.06	-6.04	-5.96%
	50%	-5.81	-6.24	-6.18	-6.16	-6.06	-6.28	-6.22	-6.14	-6.14%
7.7 to 5.7 vol% (L) (Sulfur 12 to 14)	10%	-0.26	-0.33	-0.50	-0.47	-0.26	-0.38	-0.43	-0.48	-0.39%
	25%	-0.05	-0.05	-0.20	-0.43	-0.03	-0.09	-0.32	-0.45	-0.20%
	50%	0.28	0.34	-0.11	-0.13	0.38	0.30	-0.04	-0.15	0.11%
7.7 to 5.7 vol% (H) (Sulfur 14 to 20)	10%	-2.53	-1.34	-1.01	-0.97	-2.12	-1.22	-1.02	-0.97	-1.40%
	25%	-2.68	-1.47	-1.02	-1.00	-2.30	-1.34	-1.07	-0.98	-1.48%
	50%	-2.93	-1.78	-1.35	-1.15	-2.60	-1.65	-1.29	-1.12	-1.73%
10 to 5.7 vol%	10%	-3.27	-1.64	-1.03	-0.98	-2.64	-1.33	-1.05	-0.97	-1.50%
	25%	-3.45	-1.81	-1.05	-1.02	-2.86	-1.48	-1.11	-1.00	-1.72%
	50%	-3.76	-2.20	-1.47	-1.21	-3.23	-1.89	-1.40	-1.17	-2.04%
10 to 7.7 vol%	10%	-5.17	-4.62	-4.50	-4.49	-4.98	-4.58	-4.50	-4.49	-4.67%
	25%	-5.18	-4.64	-4.52	-4.49	-5.00	-4.59	-4.51	-4.49	-4.68%
	50%	-5.20	-4.67	-4.54	-4.51	-5.03	-4.62	-4.54	-4.50	-4.70%
5.7 to 0 vol%	10%	-1.41	-3.74	-4.46	-4.66	-3.00	-4.22	-4.59	-4.69	-3.85%
	25%	-0.82	-3.25	-4.23	-4.57	-2.32	-3.78	-4.40	-4.63	-3.50%
	50%	0.15	-2.07	-3.33	-4.01	-1.18	-2.59	-3.57	-4.12	-2.59%
7.7 to 0 vol%	10%	-3.06	-4.21	-4.59	-4.69	-4.19	-4.55	-4.68	-4.71	-4.34%
	25%	-2.62	-3.85	-4.42	-4.63	-3.68	-4.22	-4.54	-4.66	-4.08%
	50%	-1.88	-2.98	-3.76	-4.22	-2.84	-3.34	-3.92	-4.30	-3.41%
10 to 0 vol%	10%	-3.86	-4.45	-4.65	-4.71	-4.78	-4.72	-4.72	-4.73	-4.58%
	25%	-3.48	-4.16	-4.52	-4.66	-4.36	-4.45	-4.61	-4.69	-4.37%
	50%	-2.84	-3.44	-3.98	-4.33	-3.64	-3.73	-4.11	-4.39	-3.81%

Table 11
Expected Changes in Statewide Exhaust Emissions
If All California Gasoline Transitioned to Different Ethanol Content

Transition from:	Terminal Tank Heel	Pollutant Exceeded	Average Change During Transition	Percent of CaRFG Benefiets
0 to 5.7 vol%	10%	HC	0.78%	0.31%
	25%	HC	1.12%	0.45%
	50%	HC	2.05%	0.83%
0 to 7.7 vol%	10%	HC	0.81%	0.33%
	25%	HC	1.08%	0.44%
	50%	HC	1.83%	0.74%
0 to 10 vol%	10%	HC	1.24%	0.50%
	25%	HC	1.24%	0.50%
	50%	HC	1.32%	0.53%
5.7 to 7.7 vol% (H) (Sulfur 20 to 14)	10%	NOx	0.09%	0.08%
	25%	NOx	0.18%	0.16%
	50%	NOx	0.42%	0.39%
5.7 to 7.7 vol% (L) (Sulfur 14 to 12)	10%	NOx	-0.14%	-0.13%
	25%	NOx	-0.10%	-0.09%
	50%	NOx	0.00%	0.00%
5.7 to 10 vol%	10%	NOx	-0.15%	-0.14%
	25%	NOx	0.07%	0.07%
	50%	NOx	0.69%	0.63%
7.7 to 10 vol%	10%	NOx	-0.13%	-0.12%
	25%	NOx	0.03%	0.03%
	50%	NOx	0.40%	0.37%
7.7 to 5.7 vol% (L) (Sulfur 12 to 14)	10%	HC	-0.03%	-0.01%
	25%	HC	0.05%	0.02%
	50%	HC	0.26%	0.10%
7.7 to 5.7 vol% (H) (Sulfur 14 to 20)	10%	HC	-0.40%	-0.16%
	25%	HC	-0.30%	-0.12%
	50%	HC	-0.06%	-0.02%
10 to 5.7 vol%	10%	HC	-0.24%	-0.09%
	25%	HC	-0.06%	-0.03%
	50%	HC	0.49%	0.20%
10 to 7.7 vol%	10%	HC	-0.41%	-0.17%
	25%	HC	-0.30%	-0.12%
	50%	HC	0.02%	0.01%
5.7 to 0 vol%	10%	HC	0.85%	0.34%
	25%	HC	0.51%	0.20%
	50%	HC	-0.31%	-0.12%
7.7 to 0 vol%	10%	HC	0.95%	0.38%
	25%	HC	0.70%	0.28%
	50%	HC	0.09%	0.03%
10 to 0 vol%	10%	HC	1.15%	0.46%
	25%	HC	1.01%	0.41%
	50%	HC	0.71%	0.29%

Table 12
Reid Vapor Pressures for Transitions from Oxygenated to Non-oxygenated fuel

Transition from:	Terminal Tank Heel	# Weeks into Transition Period [1]	Terminal	Station	Vehicle #1	Vehicle #2
5.7 to 0 vol%	10%	1	6.80	7.67	7.46	
	25%	1	6.50	7.53	7.35	
	50%	1	6.20	7.30	7.18	
7.7 to 0 vol% 10 to 0 vol%	10%	1	6.72	7.76	7.61	
	25%	1	6.59	7.66	7.54	
	50%	1	6.38	7.50	7.42	

[1] Emissions calculations were based on a four week transition period

Table 13
Reid Vapor Pressures for Transitions from Non-oxygenated to Oxygenated Fuel

Transition from:	Terminal Tank Heel	# Weeks into Transition Period [1]	Terminal	Station	Vehicle #1	Vehicle #2
0 to 5.7 vol%	10%	1	6.94	7.15 6.98	7.36	 7.24
	25%	1	7.12	7.29 7.15	7.47	 7.36
	50%	1	7.4	7.52 7.43	7.64	 7.57
		2	7.12	7.18 7.13	7.29	 7.24
0 to 7.7 vol% 0 to 10 vol%	10%	1	7.25	7.39 7.28	7.54	 7.45
		2	7.17	7.19 7.18	7.28	 7.25
	25%	1	7.37	7.49 7.39	7.62	 7.54
		2	7.22	7.25 7.22	7.34	 7.30
		3	7.18	7.19 7.18	7.22	 7.21
	50%	1	7.57	7.66 7.59	7.74	 7.69
		2	7.37	7.41 7.38	7.49	 7.46
		3	7.27	7.29 7.27	7.34	 7.32
		4	7.22	7.23 7.22	7.25	 7.24

[1] Emissions calculations were based on a four week transition period

Table 14

Staff Recommendations for Tank Transitions to Change Ethanol Content of CaRFG3 and Mitigation of Emissions Impact

Transition From	Potential Emission Impact:	Conditions to Prevent Emissions Increases
CARBOB to CARBOB (increasing oxygen by no more than 3%)	NOx increase	1.Sulfur of target fuel to be no more than 12 ppmw for 1st tank turnover of the transition. 2.Heel at terminal not to exceed 10% for each tank turnover during the transition
CARBOB to CARBOB (decreasing oxygen by no more than 3%)	HC increase	1.Sulfur of target fuel to be no more than 12 ppmw for 1st tank turnover of the transition. 2.Heel at terminal not to exceed 10% for each tank turnover during the transition
Non-Oxygenated to Oxygenated RFG	HC increase and likely RVP violation downstream of refinery	None known for summer. Allow transition during non-RVP season
Oxygenated RFG to Non-Oxygenated	HC increase and possible RVP violation downstream of refinery	None known for summer. Allow transition during non-RVP season.

FIGURE 1

TRANSITION FROM ETHANOL FUEL (A) TO ETHANOL FUEL (B)

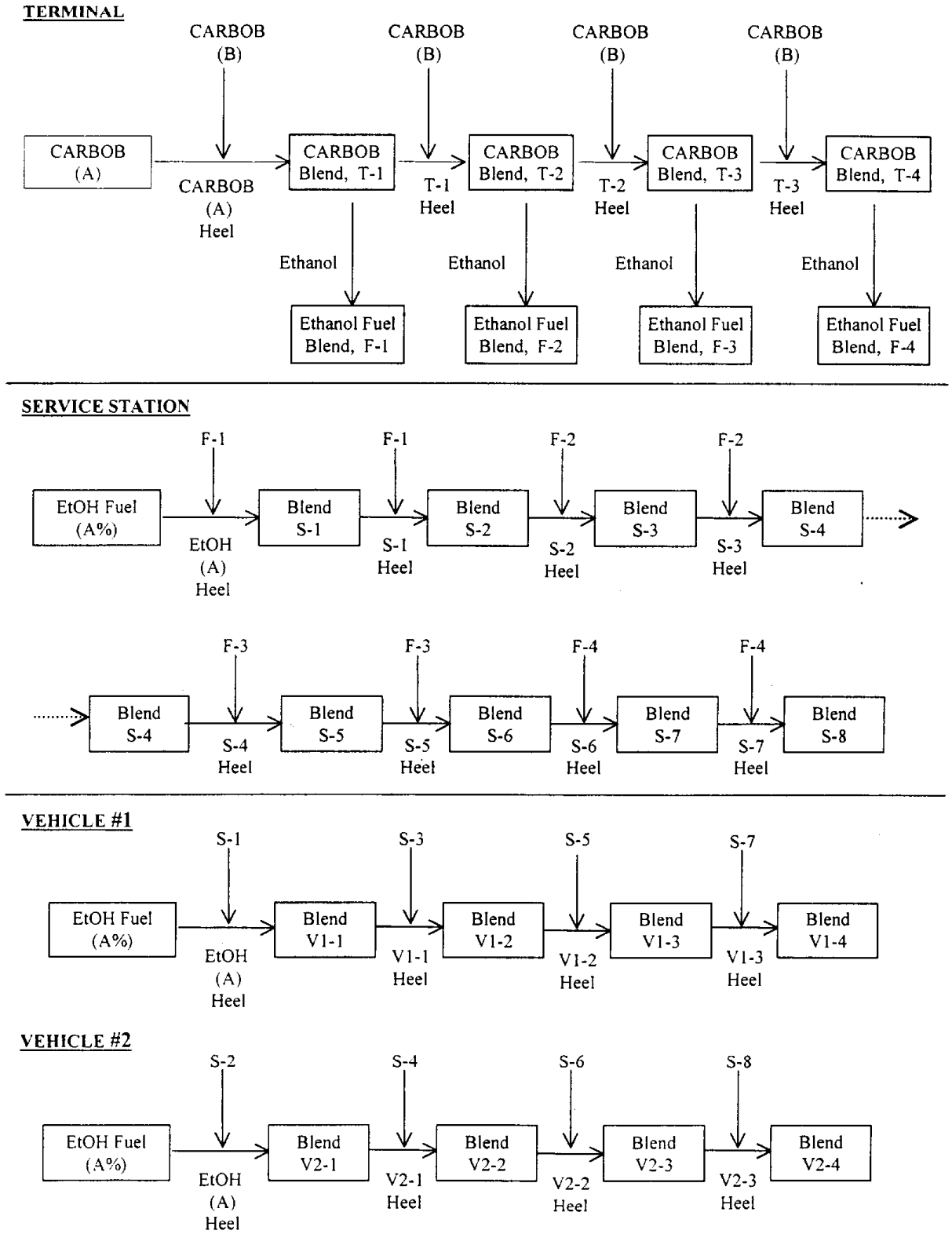

TABLE 15: EXAMPLE CALCULATION FOR TRANSITION FROM NON-OXYGENATED FUEL TO 7.7 VOL % ETHANOL FUEL

TERMINAL TANK TRANSITION: 0-OXY CaRFG TO TARGET CARBOB FOR 7.7 VOL.% EtOH

PROPERTIES OF CARBOBS AT EACH TANK TURNOVER

CARBOB Properties	0-OXY CaRFG	TARGET CARBOB (7.7 vol% EtOH)	1st Turnover CARBOB	2nd Turnover CARBOB	3rd Turnover CARBOB	4th Turnover CARBOB
Aromatics, vol%	25.0	27.0	26.8	27.0	27.0	27.0
Benzene, vol%	0.6	0.75	0.74	0.75	0.75	0.75
Olefins, vol%	6.0	4.3	4.5	4.3	4.3	4.3
Sulfur, ppm	10	14	13.6	14	14	14
T50, deg. F	210	213	213	213	213	213
T90, deg. F	305	313	312	313	313	313
Oxygen, wt. %	0.0	0	0.0	0.0	0.0	0.0
RVP, psi	6.8	6.0	6.0	6.0	6.0	6.0

PROPERTIES OF FUELS PRODUCED FROM CARBOBS

FUEL Properties	0-OXY CaRFG	TARGET FUEL from CARBOB (7.7 vol% EtOH)	FUEL from 1st Turnover CARBOB	FUEL from 2nd Turnover CARBOB	FUEL from 3rd Turnover CARBOB	FUEL from 4th Turnover CARBOB
Aromatics, vol%	25.0	25.1	24.9	25.0	25.1	25.1
Benzene, vol%	0.60	0.70	0.69	0.70	0.70	0.70
Olefins, vol%	6.0	4.0	4.2	4.0	4.0	4.0
Sulfur, ppm	10.0	14.1	13.7	14.0	14.1	14.1
T50, deg. F	210	206	206	206	206	206
T90, deg. F	305	310	309	309	310	310
Ethanol, vol.%	0.0	7.7	7.7	7.7	7.7	7.7
Oxygen	0.0	2.8	2.8	2.8	2.8	2.8
RVP, psi	6.80	7.16	7.25	7.17	7.16	7.16

NOTES: PROPERTIES OF BLENDED ETHANOL FUELS CALCULATED USING WSPA CARBOB MODEL (7/20/00)
CARBOBS FROM TERMINAL TANK TURNOVERS BLENDED
WITH ETHANOL AT TARGET CONCENTRATION OF: **7.7 VOL.% EtOH**

PROPERTIES OF FUELS EVALUATED USING THE PHASE 3 PREDICTIVE MODEL

PREDICTED PERCENT CHANGE IN EMISSIONS (CANDIDATE VS REFERENCE)

POLLUTANT	0-OXY CaRFG	TARGET FUEL from CARBOB (7.7 vol% EtOH)	FUEL from 1st Turnover CARBOB	FUEL from 2nd Turnover CARBOB	FUEL from 3rd Turnover CARBOB	FUEL from 4th Turnover CARBOB
NOX	-3.51	-0.10	-0.10	-0.09	-0.08	-0.08
EXHAUST THC	1.02	-2.88	-3.27	-2.98	-2.95	-2.95
EVAP THC (Reactivity Weighted)	-2.35	6.55	8.85	6.87	6.68	6.66
CO (Reactivity Weighted)	0.00	-0.09	-0.09	-0.09	-0.09	-0.09
TOTAL THC+CO	-0.07	-0.51	-0.06	-0.47	-0.52	-0.52
POT.TOX.	-4.86	-4.39	-4.92	-4.52	-4.48	-4.48
	PASSES	**PASSES**	**PASSES**	**PASSES**	**PASSES**	**PASSES**

THE CANDIDATE FUEL **PASSES** IF THE PERCENT CHANGE IN EMISSIONS BETWEEN THE CANDIDATE FUEL AND REFERENCE FUEL IS LESS THAN OR EQUAL TO 0.04%

THE CANDIDATE FUEL **FAILS** IF THE PERCENT CHANGE IN EMISSIONS BETWEEN THE CANDIDATE FUEL AND REFERENCE FUEL IS GREATER THAN OR EQUAL TO 0.05%

TERMINAL TANK TURNOVERS

1ST TERMINAL TANK TURNOVER		**RVP = 7.25**	**EXCEEDS CAP**
Heel (base CARBOB)	0-OXY CaRFG	10% of tank capacity	**PASSES**
New batch	TARGET CARBOB (7.7 vol% EtOH)	90% of tank capacity	
2ND TERMINAL TANK TURNOVER			
Heel	1st Turnover CARBOB	10% of tank capacity	**PASSES**
New batch	TARGET CARBOB (7.7 vol% EtOH)	90% of tank capacity	
3RD TERMINAL TANK TURNOVER			
Heel	2nd Turnover CARBOB	10% of tank capacity	**PASSES**
New batch	TARGET CARBOB (7.7 vol% EtOH)	90% of tank capacity	
4TH TERMINAL TANK TURNOVER			
Heel	3rd Turnover CARBOB	10% of tank capacity	**PASSES**
New batch	TARGET CARBOB (7.7 vol% EtOH)	90% of tank capacity	

TABLE 16: EXAMPLE CALCULATION FOR TRANSITION FROM NON-OXYGENATED FUEL TO 7.7 VOL % ETHANOL FUEL

UNDERGROUND TANK TRANSITION 0-OXY CaRFG TO 7.7 VOL.% EtOH

NEW BATCHES OF FUELS DELIVERED TO STATION

FUEL Properties	0-OXY CaRFG	FUEL from 1st Turnover CARBOB	FUEL from 1st Turnover CARBOB	FUEL from 2nd Turnover CARBOB	FUEL from 2nd Turnover CARBOB	FUEL from 3rd Turnover CARBOB	FUEL from 3rd Turnover CARBOB	FUEL from 4th Turnover CARBOB	FUEL from 4th Turnover CARBOB
Aromatics, vol%	25.0	24.9	24.9	25.0	25.0	25.1	25.1	25.1	25.1
Benzene, vol%	0.60	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70
Olefins, vol%	6.0	4.2	4.2	4.0	4.0	4.0	4.0	4.0	4.0
Sulfur, ppm	10	14	14	14	14	14	14	14	14
T50, deg. F	210	206	206	206	206	206	206	206	206
T90, deg. F	305	309	309	309	309	310	310	310	310
Ethanol conc., vol.%	0.0	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Oxygen	0.0	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
RVP, psi	6.80	7.25	7.25	7.17	7.17	7.16	7.16	7.16	7.16

NOTES: FUELS DELIVERED TO STATION WERE PRODUCED BY BLENDING CARBOBS FROM TERMINAL TANK TURNOVERS WITH ETHANOL AT TARGET ETHANOL CONCENTRATION OF : 7.7 VOL.% EtOH

HEEL IN UNDERGROUND TANK: **20%** OF TANK CAPACITY

CARBOB HEEL IN TERMINAL TANK WAS **10%** OF TANK CAPACITY

UNDERGROUND TANK TRANSITION FROM 0-OXY CaRFG TO 7.7 vol% EtOH FUEL

FUELS PRODUCED BY MIXING UNDERGROUND TANK HEEL WITH NEW BATCH OF FUEL

FUEL Properties	0-OXY CaRFG	1st Turnover FUEL at STATION	2nd Turnover FUEL at STATION	3rd Turnover FUEL at STATION	4th Turnover FUEL at STATION	5th Turnover FUEL at STATION	6th Turnover FUEL at STATION	7th Turnover FUEL at STATION	8th Turnover FUEL at STATION	7.7 vol% EtOH FUEL
Aromatics, vol%	25.0	24.9	24.9	25.0	25.0	25.0	25.0	25.1	25.1	25.1
Benzene, vol%	0.60	0.67	0.68	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Olefins, vol%	6.0	4.5	4.2	4.1	4.0	4.0	4.0	4.0	4.0	4.0
Sulfur, ppm	10	13	14	14	14	14	14	14	14	14
T50, deg. F	210	207	206	206	206	206	206	206	206	206
T90, deg. F	305	308	309	309	309	310	310	310	310	310
Ethanol conc., vol.%	0.0	6.2	7.4	7.6	7.7	7.7	7.7	7.7	7.7	7.7
Oxygen, wt. %	0.0	2.2	2.7	2.8	2.8	2.8	2.8	2.8	2.8	2.8
RVP, psi	6.80	7.39	7.28	7.19	7.18	7.17	7.17	7.16	7.16	7.16

NOTES: HEEL IN UNDERGROUND STORAGE TANK **20.0% of tank capacity**

USE ROCKE'S EQUATION TO CALCULATE RVP BOOST FOR FIRST UNDERGROUND TANK TURNOVER

RVP BOOST = 1.19 psi FOR HEEL FOR FIRST UNDERGROUND TANK TURNOVER

PROPERTIES OF FUELS EVALUATED USING THE PHASE 3 PREDICTIVE MODEL

PREDICTED PERCENT CHANGE IN EMISSIONS (CANDIDATE VS REFERENCE)

POLLUTANT	0-OXY CaRFG	1st Turnover FUEL at STATION	2nd Turnover FUEL at STATION	3rd Turnover FUEL at STATION	4th Turnover FUEL at STATION	5th Turnover FUEL at STATION	6th Turnover FUEL at STATION	7th Turnover FUEL at STATION	8th Turnover FUEL at STATION	7.7 vol% EtOH FUEL
NOX	-3.51	-1.30	-0.09	-0.09	-0.09	-0.08	-0.08	-0.08	-0.08	-0.10
EXHAUST THC	1.02	-2.60	-3.27	-3.04	-2.99	-2.96	-2.95	-2.95	-2.95	-2.88
EVAP THC (Reactivity Weighted)	-2.35	13.01	9.66	7.42	6.98	6.74	6.69	6.66	6.66	6.55
CO (Reactivity Weighted)	0.00	-0.03	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09
TOTAL THC+CO	-0.07	2.10	0.19	-0.34	-0.45	-0.50	-0.51	-0.52	-0.52	-0.51
POT.TOX.	-4.86	-4.53	-4.89	-4.60	-4.54	-4.49	-4.49	-4.48	-4.48	-4.39
	PASSES	FAILS	FAILS	PASSES	PASSES	PASSES	PASSES	PASSES	PASSES	PASSES

UNDERGROUND TANK TRANSITION 0-OXY CaRFG TO 7.7 VOL.% EtOH

CARBOB HEEL IN TERMINAL TANK WAS 10% OF TANK CAPACITY

UNDERGROUND TANK TURNOVERS

1ST UNDERGROUND TANK TURNOVER: RVP = 7.39 EXCEEDS CAP

Heel (base fuel): 0-OXY CaRFG 20.0% of tank capacity

New batch FUEL from 1st Turnover CARBOB 80.0% of tank capacity FAILS

2ND UNDERGROUND TANK TURNOVER: RVP = 7.28 EXCEEDS CAP

Heel: 1st Turnover FUEL at STATION 20.0% of tank capacity

New batch FUEL from 1st Turnover CARBOB 80.0% of tank capacity FAILS

3RD UNDERGROUND TANK TURNOVER:

Heel: 2nd Turnover FUEL at STATION 20.0% of tank capacity

New batch FUEL from 2nd Turnover CARBOB 80.0% of tank capacity PASSES

4TH UNDERGROUND TANK TURNOVER:

Heel: 3rd Turnover FUEL at STATION 20.0% of tank capacity

New batch FUEL from 2nd Turnover CARBOB 80.0% of tank capacity PASSES

5TH UNDERGROUND TANK TURNOVER:

Heel: 4th Turnover FUEL at STATION 20.0% of tank capacity

New batch FUEL from 3rd Turnover CARBOB 80.0% of tank capacity PASSES

6TH UNDERGROUND TANK TURNOVER:

Heel: 5th Turnover FUEL at STATION 20.0% of tank capacity

New batch FUEL from 3rd Turnover CARBOB 80.0% of tank capacity PASSES

7TH UNDERGROUND TANK TURNOVER:

Heel: 6th Turnover FUEL at STATION 20.0% of tank capacity

New batch FUEL from 4th Turnover CARBOB 80.0% of tank capacity PASSES

8TH UNDERGROUND TANK TURNOVER:

Heel: 7th Turnover FUEL at STATION 20.0% of tank capacity

New batch FUEL from 4th Turnover CARBOB 80.0% of tank capacity PASSES

THE CANDIDATE FUEL **PASSES** IF THE PERCENT CHANGE IN EMISSIONS BETWEEN THE CANDIDATE FUEL AND REFERENCE FUEL IS LESS THAN OR EQUAL TO 0.04%

THE CANDIDATE FUEL **FAILS** IF THE PERCENT CHANGE IN EMISSIONS BETWEEN THE CANDIDATE FUEL AND REFERENCE FUEL IS GREATER THAN OR EQUAL TO 0.05%

TABLE 17: EXAMPLE CALCULATION FOR TRANSITION FROM NON-OXYGENATED FUEL TO 7.7 VOL % ETHANOL FUEL

VEHICLE TANK TRANSITION FROM 0-OXY CaRFG TO 7.7 vol% EtOH FUEL

VEHICLE #1

NEW BATCHES OF FUELS PRODUCED AT STATION WITH EACH UNDERGROUND TANK TURNOVER

FUEL Properties	0-OXY CaRFG	1st Turnover FUEL at STATION	3rd Turnover FUEL at STATION	5th Turnover FUEL at STATION	7th Turnover FUEL at STATION	7.7 vol% EtOH FUEL
Aromatics, vol%	25.0	24.9	25.0	25.0	25.1	25.1
Benzene, vol%	0.60	0.67	0.70	0.70	0.70	0.70
Olefins, vol%	6.0	4.5	4.1	4.0	4.0	4.0
Sulfur, ppm	10	13	14	14	14	14
T50, deg. F	210	207	206	206	206	206
T90, deg. F	305	308	309	310	310	310
Ethanol conc. vol.%	0.0	6.2	7.6	7.7	7.7	7.7
Oxygen, wt. %	0.0	2.2	2.8	2.8	2.8	2.8
RVP, psi	6.80	7.39	7.19	7.17	7.16	7.16

FUELS AT STATION PRODUCED BY MIXING UNDERGROUND TANK HEEL WITH NEW BATCH OF FUEL DELIVERED TO STATION

HEEL IN UNDERGROUND TANK: **20.0% of tank capacity**

HEEL IN TERMINAL TANK: **10% of tank capacity**

VEHICLE #1

FUELS IN VEHICLE TANK PRODUCED BY MIXING VEHICLE TANK HEEL WITH NEW BATCH OF FUEL AT STATION

FUEL Properties	0-OXY CaRFG	1st Turnover FUEL in VEHICLE #1	2nd Turnover FUEL in VEHICLE #1	3rd Turnover FUEL in VEHICLE #1	4th Turnover FUEL in VEHICLE #1	7.7 vol% EtOH FUEL
Aromatics, vol%	25.0	24.9	25.0	25.0	25.0	25.1
Benzene, vol%	0.60	0.65	0.68	0.70	0.70	0.70
Olefins, vol%	6.0	4.9	4.3	4.1	4.0	4.0
Sulfur, ppm	10.0	12.2	13.5	13.9	14.0	14.1
T50, deg. F	210	207	206	206	206	206
T90, deg. F	305	307	309	309	309	310
Ethanol conc. vol.%	0.0	4.6	6.9	7.5	7.6	7.7
Oxygen, wt. %	0.0	1.7	2.5	2.7	2.8	2.8
RVP, psi	6.80	7.54	7.28	7.20	7.17	7.16

NOTE: HEEL IN VEHICLE TANK: **25% of tank capacity**

HEEL IN UNDERGROUND TANK: **20% of tank capacity**

HEEL IN TERMINAL TANK: **10% of tank capacity**

RVP BOOST = 1.19 psi FOR FIRST VEHICLE TANK TURNOVER

PROPERTIES OF FUELS IN VEHICLE TANK EVALUATED USING THE PHASE 3 PREDICTIVE MODEL

PREDICTED PERCENT CHANGE IN EMISSIONS (CANDIDATE VS REFERENCE)

POLLUTANT	0-OXY CaRFG	1st Turnover FUEL in VEHICLE #1	2nd Turnover FUEL in VEHICLE #1	3rd Turnover FUEL in VEHICLE #1	4th Turnover FUEL in VEHICLE #1	7.7 vol% EtOH FUEL
NOX	-3.51	-2.38	-0.66	-0.08	-0.08	-0.10
EXHAUST THC	1.02	-1.76	-2.80	-2.99	-2.96	-2.88
EVAP THC (Reactivity Weighted)	-2.35	17.37	9.80	7.49	6.87	6.55
CO (Reactivity Weighted)	0.00	0.00	-0.06	-0.09	-0.09	-0.09
TOTAL THC+CO	-0.07	4.18	0.74	-0.29	-0.46	-0.51
POT.TOX.	-4.86	-4.06	-4.50	-4.52	-4.49	-4.39
	PASSES	**FAILS**	**FAILS**	**PASSES**	**PASSES**	**PASSES**

THE CANDIDATE FUEL **PASSES** IF THE PERCENT CHANGE IN EMISSIONS BETWEEN THE CANDIDATE FUEL AND REFERENCE FUEL IS LESS THAN OR EQUAL TO 0.04%

THE CANDIDATE FUEL **FAILS** IF THE PERCENT CHANGE IN EMISSIONS BETWEEN THE CANDIDATE FUEL AND REFERENCE FUEL IS GREATER THAN OR EQUAL TO 0.05%

VEHICLE TANK TURNOVERS

VEHICLE#1

1ST VEHICLE TANK TURNOVER:		RVP = 7.54	EXCEEDS CAP	
Heel (base fuel):	0-OXY CaRFG	25.0%	of tank capacity	
New batch	1st Turnover FUEL at STATION	75.0%	of tank capacity	**FAILS**
2ND VEHICLE TANK TURNOVER:		RVP = 7.28	EXCEEDS CAP	
Heel:	1st Turnover FUEL in VEHICLE #1	25.0%	of tank capacity	
New batch	3rd Turnover FUEL at STATION	75.0%	of tank capacity	**FAILS**
3RD VEHICLE TANK TURNOVER:				
Heel:	2nd Turnover FUEL in VEHICLE #1	25.0%	of tank capacity	
New batch	5th Turnover FUEL at STATION	75.0%	of tank capacity	**PASSES**
4TH VEHICLE TANK TURNOVER:				
Heel:	3rd Turnover FUEL in VEHICLE #1	25.0%	of tank capacity	
New batch	7th Turnover FUEL at STATION	75.0%	of tank capacity	**PASSES**

TABLE 18: EXAMPLE CALCULATION FOR TRANSITION FROM NON-OXYGENATED FUEL TO 7.7 VOL % ETHANOL FUEL

VEHICLE TANK TRANSITION FROM 0-OXY CaRFG TO 7.7 vol% EtOH FUEL

VEHICLE #2

NEW BATCHES OF FUELS PRODUCED AT STATION WITH EACH UNDERGROUND TANK TURNOVER

FUEL Properties	0-OXY CaRFG	2nd Turnover FUEL at STATION	4th Turnover FUEL at STATION	6th Turnover FUEL at STATION	8th Turnover FUEL at STATION	7.7 vol% EtOH FUEL
Aromatics, vol%	25.0	24.9	25.0	25.0	25.1	25.1
Benzene, vol%	0.60	0.68	0.70	0.70	0.70	0.70
Olefins, vol%	6.0	4.2	4.0	4.0	4.0	4.0
Sulfur, ppm	10	13.6	14.0	14.1	14.1	14
T50, deg. F	210	206	206	206	206	206
T90, deg. F	305	309	309	310	310	310
Ethanol conc., vol.%	0.0	7.4	7.7	7.7	7.7	7.7
Oxygen, wt. %	0.0	2.7	2.8	2.8	2.8	2.8
RVP, psi	6.80	7.28	7.18	7.17	7.16	7.16

FUELS AT STATION PRODUCED BY MIXING UNDERGROUND TANK HEEL WITH NEW BATCH OF FUEL DELIVERED TO STATION

HEEL IN UNDERGROUND TANK: **20.0% of tank capacity**

HEEL IN TERMINAL TANK: **10% of tank capacity**

VEHICLE #2

FUELS IN VEHICLE TANK PRODUCED BY MIXING VEHICLE TANK HEEL WITH NEW BATCH OF FUEL AT STATION

FUEL Properties	0-OXY CaRFG	1st Turnover FUEL in VEHICLE #2	2nd Turnover FUEL in VEHICLE #2	3rd Turnover FUEL in VEHICLE #2	4th Turnover FUEL in VEHICLE #2	7.7 vol% EtOH FUEL
Aromatics, vol%	25.0	24.9	25.0	25.0	25.0	25.1
Benzene, vol%	0.60	0.66	0.69	0.70	0.70	0.70
Olefins, vol%	6.0	4.7	4.2	4.1	4.0	4.0
Sulfur, ppm	10	12.7	13.7	14.0	14.1	14.0
T50, deg. F	210	207	206	206	206	206
T90, deg. F	305	308	309	309	310	310
Ethanol conc. vol %	0.0	5.5	7.2	7.6	7.7	7.7
Oxygen, wt. %	0.0	2.0	2.6	2.7	2.8	2.8
RVP, psi	6.80	7.45	7.25	7.19	7.17	7.16

NOTE: HEEL IN VEHICLE TANK: **25% of tank capacity**

HEEL IN UNDERGROUND TANK: **20% of tank capacity**

HEEL IN TERMINAL TANK: **10% of tank capacity**

RVP BOOST = 1.19 psi FOR FIRST VEHICLE TANK TURNOVER

PROPERTIES OF FUELS IN VEHICLE TANK EVALUATED USING THE PHASE 3 PREDICTIVE MODEL

PREDICTED PERCENT CHANGE IN EMISSIONS (CANDIDATE VS REFERENCE)

POLLUTANT	0-OXY CaRFG	1st Turnover FUEL in VEHICLE #2	2nd Turnover FUEL in VEHICLE #2	3rd Turnover FUEL in VEHICLE #2	4th Turnover FUEL in VEHICLE #2	7.7 vol% EtOH FUEL
NOX	-3.51	-1.79	-0.08	-0.08	-0.08	-0.10
EXHAUST THC	1.02	-2.26	-3.06	-2.98	-2.95	-2.88
EVAP THC (Reactivity Weighted)	-2.35	14.73	8.85	7.22	6.80	6.55
CO (Reactivity Weighted)	0.00	0.00	-0.09	-0.09	-0.09	-0.09
TOTAL THC+CO	-0.07	3.06	0.08	-0.37	-0.48	-0.51
POT.TOX.	-4.86	-4.34	-4.59	-4.51	-4.49	-4.39
	PASSES	FAILS	FAILS	PASSES	PASSES	PASSES

THE CANDIDATE FUEL **PASSES** IF THE PERCENT CHANGE IN EMISSIONS BETWEEN THE CANDIDATE FUEL AND REFERENCE FUEL IS LESS THAN OR EQUAL TO 0.04%

THE CANDIDATE FUEL **FAILS** IF THE PERCENT CHANGE IN EMISSIONS BETWEEN THE CANDIDATE FUEL AND REFERENCE FUEL IS GREATER THAN OR EQUAL TO 0.05%

VEHICLE TANK TURNOVERS

VEHICLE#2

1ST VEHICLE TANK TURNOVER:		RVP = 7.45	EXCEEDS CAP	
Heel:	0-OXY CaRFG	25.0% of tank capacity		
New batch	2nd Turnover FUEL at STATION	75.0% of tank capacity		FAILS
2ND VEHICLE TANK TURNOVER:		RVP = 7.25	EXCEEDS CAP	
Heel:	1st Turnover FUEL in VEHICLE #2	25.0% of tank capacity		
New batch	4th Turnover FUEL at STATION	75.0% of tank capacity		FAILS
3RD VEHICLE TANK TURNOVER:				
Heel:	2nd Turnover FUEL in VEHICLE #2	25.0% of tank capacity		
New batch	6th Turnover FUEL at STATION	75.0% of tank capacity		PASSES
4TH VEHICLE TANK TURNOVER:				
Heel:	3rd Turnover FUEL in VEHICLE #2	25.0% of tank capacity		
New batch	8th Turnover FUEL at STATION	75.0% of tank capacity		PASSES