State of California
California Environmental Protection Agency
AIR RESOURCES BOARD

California Procedures for Evaluating Alternative Specifications for Phase 2 Reformulated Gasoline Using the California Predictive Model

Adopted: April 20, 1995
Amended: December 11, 1998

Note: The amendment adopted December 11, 1998 is shown in underline to indicate an addition and ~~strikeout~~ to indicate a deletion. The only amendment is in Section I.A. Table 1, where the identified cap limit for maximum oxygen content is changed from 2.7 wt.% to 3.5 wt.%. In light of the limited nature of the amendment, this document does not show the Table of Contents, the List of Tables, or the text following Section 1.A.

California Procedures for Evaluating Alternative Specifications for Phase 2 Reformulated Gasoline Using the California Predictive Model

I. INTRODUCTION

A. Purpose and Applicability

1. The predictive model prescribed in this document may be used to evaluate gasoline specifications as alternatives to the gasoline specifications set forth in Title 13, California Code of Regulations (13 CCR), sections 2262.1 through 2262.7.

   This procedure:

   - prescribes the range of specifications that may be utilized to select a set of candidate Phase 2 RFG alternative gasoline specifications for evaluation,
   - defines the Phase 2 RFG reference specifications,
   - prescribes the calculations to be used to predict the emissions from the candidate specifications and the reference Phase 2 RFG specifications,
   - prescribes the calculations to be used to compare the emissions resulting from the candidate specifications to the reference Phase 2 RFG specifications,
   - establishes the requirements for the demonstration and approval of the candidate specifications as an alternative Phase 2 RFG formulation, and
   - establishes the notification requirements.

2. Gasoline properties for which alternative gasoline specifications may be set by this procedure include all eight Phase 2 RFG properties, except Reid vapor pressure (RVP).

3. The Phase 2 RFG specifications, established in 13 CCR, sections 2262.1 through 2262.7; are shown in Table 1.

Table 1
Properties and Specifications for Phase 2 Reformulated Gasoline

Fuel Property	Units	Flat Limit	Averaging Limit	Cap Limit
Reid vapor pressure (RVP)	psi, max.	7.00[1]	none	7.00
Sulfur (SUL)	ppmw, max.	40	30	80
Benzene (BENZ)	vol.%, max.	1.00	0.80	1.20
Aromatic HC (AROM)	vol.%, max.	25.0	22.0	30.0
Olefin (OLEF)	vol.%, max.	6.0	4.0	10
Oxygen (OXY)	wt. %	1.8 (min) 2.2 (max)	none	1.8(min)[2] ~~2.7~~ 3.5 (max)
Temperature at 50% distilled (T50)	deg. F, max.	210	200	220
Temperature at 90% distilled (T90)	deg. F, max.	300	290	330

[1] Applicable during the summer months identified in 13 CCR, sections 2262.1 (a) and (b).
[2] Applicable during the winter months identified in 13 CCR, section 2262.5 (a).

4. The pollutant emissions addressed by these procedures and the units of measurement are shown in Table 2.

Table 2
Predictive Model Pollutants and Units of Measurement

Pollutant Emissions	Units
Oxides of nitrogen (NOx)	gm/mile
Hydrocarbons (HC)	gm/mile
Potency-weighted Toxics (PWT)	mg/mile

* * * *

State of California
AIR RESOURCES BOARD

CALIFORNIA ~~TEST~~ PROCEDURES FOR EVALUATING ALTERNATIVE SPECIFICATIONS FOR GASOLINE USING VEHICLE EMISSIONS TESTING

Adopted: September 18, 1992
Amended: April 25, 2001

Note: The adopted amendments are shown in underline to indicate additions and ~~strikeout~~ to indicate deletions.

California ~~Test~~ Procedures for Evaluating Alternative Specifications for Gasoline Using Vehicle Emissions Testing

I. INTRODUCTION

A. Purpose and Applicability

1. The test procedures and analyses prescribed in this document ("test protocol") may be used to evaluate gasoline specifications proposed as alternatives to the Phase 2 California reformulated gasoline (CaRFG) flat limit specifications or the Phase 3 CaRFG flat limit specifications set forth in ~~Chapter 5, Article 1, subarticle 2,~~ sections ~~2260~~ 2262 ~~et. seq.~~, ~~T~~title 13, California Code of Regulations (collectively referred to herein as the "~~adopted gasoline specifications~~ CaRFG flat limit specifications").

*[**Commentary:** The modifications allow the procedures to be used to identify formulations that are equivalent to either the Phase 2 CaRFG or Phase 3 CaRFG standards. The specific references to the flat limits are added for clarity, since the Procedures are not available for establishing alternatives to averaging limits.]*

2. Gasoline properties for which alternative specifications may be set by this protocol include all properties having ~~adopted gasoline specifications~~ CaRFG flat limit specifications, except Reid vapor pressure (RVP) and the Phase 3 CaRFG prohibition of MTBE. Any other properties not ~~regulated by the code stated in I.A.1.~~ covered by the CaRFG flat limit specifications also may receive specifications by this protocol.

*[**Commentary:** The modifications make clear that the MTBE prohibition applies to alternative formulations, and make other provisions more specific and clearer.]*

3. Limits on the values allowable for certain specifications are as follows, reflecting the cap limits in section 2262, title 13, California Code of Regulations:

For Alternatives to the Phase 2 CaRFG Flat Limit Specifications

benzene	--	not to exceed 1.20 volume percent
olefin (total)	--	not to exceed 10 volume percent
olefin (C3 to C5)	--	not to exceed 1 volume percent
sulfur	--	not to exceed 80 ppm
aromatic hydrocarbon	--	not to exceed 30 volume percent
oxygen	--	not to exceed 2.7 wt. percent
	--	minimum of 1.8 wt. percent during specified winter months in areas identified in section 2261(b)(1)(A), title 13, CCR.

distillation temp.		
T90	--	not to exceed 330 degrees F
T50	--	not to exceed 220 degrees F

For Alternatives to the Phase 3 CaRFG Flat Limit Specifications

benzene	--	not to exceed 1.10 volume percent
olefin (total)	--	not to exceed 10 volume percent
olefin (C3 to C5)	--	not to exceed 1 volume percent
sulfur	--	not to exceed 60 ppm (December 31, 2002 - December 30, 2004)
		not to exceed 30 ppm (starting December 31, 2004)
aromatic hydrocarbon	--	not to exceed 35 volume percent
oxygen	--	not to exceed 3.5 wt. percent[1]
	--	minimum of 1.8 wt. percent during specified winter months in areas identified in section 2262.5(b)(1)(A), title 13, CCR.
distillation temp.		
T90	--	not to exceed 330 degrees F
T50	--	not to exceed 220 degrees F

[1] If the gasoline contains more than 3.5 percent by weight oxygen but no more than 10 volume percent ethanol, the maximum oxygen content is 3.7 percent by weight.

[Commentary; The modification to the Phase 2 CaRFG table clarifies the preexisting intent that the alternative specifications are not available to substitute for any wintertime oxygenate requirements; this is the case with the Predictive Model mechanism as well. Adding caps for alternatives to the Phase 3 CaRFG standards will continue the availability of the procedures after December 30, 2002.]

4. The pollutant measures addressed by this protocol are carbon monoxide emissions (CO, gm/mile), oxides of nitrogen emissions (NOx, gm/mile), exhaust emissions of non-methane organic gases (NMOG, gm/mile), the combined ozone forming potential of exhaust NMOG emissions (gm. ozone/mile), and the combined potency-weighted emissions of toxic air contaminants in exhaust (mg/mile).

B. Synopsis of Protocol

The difference in emissions between the test fuel and the reference fuel (test fuel emissions minus reference fuel emissions, in grams/mile) is computed for tests in each test vehicle and then averaged over all vehicles within each of several vehicle categories in a test fleet. These average differences by category are combined into a mileage-weighted mean that serves as an estimate of the difference in average emissions per mile between the test and reference fuels in the relevant on-road vehicle fleet. A statistical

upper bound for this mileage-weighted estimate is computed. A mileage-weighted estimate of average emissions per mile from the reference fuel among the on-road vehicle fleet is also computed, using the same weights.

For each pollutant, the statistical upper bound for the average difference in emissions is compared to a specified "tolerance" fraction of the average emissions of that pollutant from the reference fuel. If the statistical upper bound is the greater of these two numbers for any pollutant, the candidate fuel cannot be approved.

C. Definitions

1. "Applicant" means that the party seeking approval of alternative gasoline specifications and responsible for the demonstration described in Section II.

2. "Reference fuel" means a gasoline meeting the following specifications:

Phase 2 CaRFG Reference Fuel Specifications

Property	*Test Method*	*Specification*
Research Octane, min.	D2699	93
Sensitivity, min.		7.5
Lead (organic), max., g/US gal	D3237	0.050
Distillation Range		
10 pct. point, degrees F	D86-90	130-140
50 pct. point, degrees F	D86-90	190-210
90 pct. point, degrees F	D86-90	280-300
Sulfur, max. ppm wt.	D2622-87	40
Phosphorus, max., g/US gal		0.005
RVP, psi	D323-58 or 13 CCR sec. 2297	6.7-7.0
Olefins, maximum pct.	1319-89	6.0
Aromatics, maximum pct.	ARB MLD 116	25.0
Oxygen, wt. pct.	4815-89	1.8-2.2
Benzene, max. vol. pct.	3606-87	1.00

Phase 3 CaRFG Reference Fuel Specifications

Property	*Test Method*	*Specification*
Research Octane, min.	D2699	93
Sensitivity, min.		7.5
Lead (organic), max., g/US gal	D3237	0.050
Distillation Range		
10 pct. point, degrees F	D86-90	130-140
50 pct. point, degrees F	D86-90	190-213
90 pct. point, degrees F	D86-90	280-305
Sulfur, max. ppm wt.	D2622-87	20
Phosphorus, max., g/US gal		0.005
RVP, psi	D323-58 or 13 CCR sec. 2297	6.7-7.0
Olefins, maximum pct.	1319-89	6.0
Aromatics, maximum pct.	ARB MLD 116	25.0
Oxygen, wt. pct.	4815-89	1.8-2.2
Benzene, max. vol. pct.	3606-87	0.80

*[**Commentary**: In the reference fuel specifications for Phase 3 CaRFG3, the specifications for benzene, sulfur, T50 and T90 have been changed to reflect the new Phase 3 CaRFG flat limits for these properties.]*

3. "Candidate fuel" means any gasoline that would meet specifications proposed as alternatives to the specifications cited in I.A.1. All candidate fuels under a particular set of proposed specifications are represented in the emission demonstration by the test fuel.

4. "Duplicate test" means an emission test run on a particular vehicle and a particular fuel as a repetition of the preceding test on the same vehicle and fuel, without draining and re-filling the fuel tank and conducting pre-test ~~dynomometer~~ dynamometer cycles, as described in VII.D., between the tests.

5. "LDV" means light-duty cycle. "MDV" means medium-duty vehicle. "TLEV" means transitional low-emission vehicle. "LEV" means low-emission vehicle. "ULEV" means ultra-low emission vehicle. "SULEV" means super ultra-low emission vehicle, all as defined in ~~T~~title 13, California Code of Regulations, section 1960.1. "Low-emission vehicle" includes LEVs, TLEVs, ~~and~~ ULEVs, and SULEVs. For the purpose of this protocol, only vehicles capable of using gasoline are included among low-emission vehicles.

[Commentary: The SULEV category has been added to the ARB's exhaust emission standards since the original adoption of this Procedures document.]

6. "Replicate test" means an emission test or a set of duplicate tests run on a particular vehicle and a particular fuel as a repetition of another test or set of tests on the same vehicle and fuel, with draining and re-filling the fuel tank and the pre-test ~~dynomometer~~ dynamometer cycles, as described in VII.D., between the tests or sets of tests.

7. "Test fuel" means the particular batch of gasoline representing candidate fuels in the emission demonstration required for approval of alternative gasoline specifications.

8. "Toxic air contaminants" means exhaust emissions of benzene, 1,3-butadiene, formaldehyde, and acetaldehyde.

II. DEMONSTRATION REQUIRED FOR CANDIDATE FUELS

The demonstration of approvability of alternative specifications shall consist of emission tests on a test fuel whose properties identified per the test plan in Section VI. have been accurately measured. The values of those properties shall correspond, as described in Section VI, with the proposed specifications. Comparisons of the results of these tests with the results of tests on the reference fuel must satisfy the criterion in section IV.

III. EMISSION TESTS AND COMPARISONS REQUIRED FOR CANDIDATE FUELS

A. Emission tests and comparisons shall be done on a fleet of on-road vehicles which exist at the time of the testing. The vehicle categories appropriate for inclusion in this fleet are defined in subsection V.A.

B. Within the fleet in subsection III.A., comparisons using the criterion in section IV. shall be made between emissions measured in tests using a test fuel representing the candidate fuel and emissions measured in tests using reference fuel.

C. The criterion in section IV. shall be applied separately to CO emissions, NOx emissions, the exhaust NMOG emissions, the combined ozone-forming potential of exhaust NMOG emissions, and the combined potency-weighted emissions of toxic air contaminants. If the test fuel fails to meet the criterion in section IV. for any of these pollutants, the candidate fuel shall have failed the required demonstration.

IV. CRITERION FOR DEMONSTRATION OF ACCEPTABLE EMISSIONS

For each comparison required in section III., the upper confidence limit (UCL) for the estimated mean difference in emissions between fuels (test fuel vs. reference fuel) among all on-road vehicles in the tested categories, computed at the significance level 0.15 for the one-sided t-statistic, shall be less than or equal to a tolerance fraction (δ) of the average emissions (E_c, in grams/mile) estimated for those on-road vehicles using the reference fuel. The estimate of emission difference shall be based on the emission measurements in the test fleet. In terms of parameters calculated per section IX., the criterion is expressed as:

$$UCL = D + t_{.15,\,nu} * S.E. \leq \delta * E_c$$

where D is the estimate of the mean difference in emissions between the fuels, and S.E. is the standard error for that estimate, calculated for nu degrees of freedom.

The tolerance fractions δ shall be as follows:

Pollutant Measure	δ
CO	.040
NOx	.020
NMOG	.030
Grams Ozone/mile	.040
Potency-Weighted Toxics	.040

V. TEST VEHICLES

A. Vehicle Categories for Testing

1. For the purpose of this protocol, ~~eight~~ categories of light-duty vehicles (passenger cars and trucks) are defined by the following model years, catalyst types, and/or emission standards. Only vehicles meeting all defining descriptors for a category are included in that category.

For Alternatives to the Phase 2 CaRFG Specifications

Model Year	*Catalyst Type*	*Emission Standard*
Pre-1975	No catalyst	
1975 – 1980	Open-loop oxidizing	
1981 – 1985	Closed-loop three-way	
1986 – 1990	Closed-loop three-way	
Post-1990	(any)	not low-emission
"	(any)	TLEV
"	(any)	LEV
"	(any)	ULEV

For Alternatives to the Phase 3 CaRFG Specifications

Model Year	*Catalyst Type*	*Emission Standard*
Pre-1975	No catalyst	
1975 – 1980	Open-loop oxidizing	
1981 – 1985	Closed-loop three-way	
1986 – 1990	Closed-loop three-way	
1991 – 1995	Closed-loop three-way	
Post-1995	(any)	not low-emission
"	(any)	TLEV
"	(any)	LEV
"	(any)	ULEV
"	(any)	SULEV

[Commentary: The list of vehicle categories for test programs determining equivalency to the Phase 3 CaRFG standards reflects vehicles in later model years.]

2. The executive officer shall maintain estimates of the total emissions from, and total annual miles travelled by, vehicles in the state in each of the categories listed above. These estimates shall be for the same time as, consistent with, and updated on the same schedule as the estimates of miles travelled that the executive officer uses to determine the required numbers of new retail outlets for clean fuels under section ~~2305(d)(2) and section 2307(e)(2)~~ 2303(c), ~~T~~title 13, California Code of Regulations.

[Commentary: The updated references reflect the recent amendments to the clean fuels availability regulations.]

3. Over all vehicle categories in subsection V.A.1., the executive officer shall sum all exhaust NMOG emissions and all miles travelled in the state for the time

corresponding to the estimates described in subsection V.A.2., assuming that all the vehicles receive the reference fuel all the time.

4. The test fleet required by subsection III.A.1. shall consist of each vehicle category contributing at least 3 percent of the sum of NMOG emissions (described in subsection V.A.3.) over all categories for the fleet or at least 5 percent of the sum of miles travelled over all categories.

B. Number, Descriptions, and Preparations of Vehicles

1. Within each vehicle category to be tested per subsection V.A.4., the emission comparisons described in subsection III. shall be conducted in at least five vehicles. Over all categories tested, the total number of vehicles shall be at least 20.

2. Except in the case described in subsection V.B.6., the group of vehicles within each test category shall meet these restrictions:

   (a) no two vehicles shall be the same model and model year.

   (b) not more than 20 percent shall have the same owner or the same manufacturer.

3. Except as provided in subsection V.B.6., within each vehicle category, the test vehicles shall have distributions of engine displacement, types of fuel/air metering, catalyst technology, emission control system, and California vs. U.S. (49-state) certification that the executive officer deems are sufficiently representative of California's on-road fleet to make significant bias of the overall test results unlikely.

4. Except as provided in subsection V.B.6, each vehicle used under this protocol shall have accumulated at least the following miles travelled:

Age of vehicle, as determined by model year	*Minimum miles travelled*
0 to 1	4,000
2 to 5	18,000
6 to 10	41,000
11 to 15	61,000
>15	76,000

5. Each vehicle shall be tested in its as-received condition; except, any routine maintenance scheduled to occur per the manufacturer's recommendation may be performed.

6. If the applicant demonstrates to the executive officer that the requirements in subsection V.B. are unreasonably difficult to meet for a vehicle category and unnecessary to provide a group of vehicles that reasonably represents the vehicle category, the executive officer may relax the requirements for that vehicle category.

7. Instead of following paragraphs 2 through 5 of this subsection B., the applicant may compose each category of test vehicles required by subsection V.A.4. through random sampling of on-road vehicles. This option may be followed only after approval by the executive officer of the proposed sampling method as part of the plan described in section VI.

VI. TEST PLAN

A. The applicant shall submit to the executive officer a test plan including the following information:

1. identification of properties of the fuel that affect exhaust emissions and would require specification in commercially available fuel; these shall include (but are not limited to) all properties with adopted gasoline specifications.

2. identification of the appropriate form of specification for each property identified in VI.A.1.; each specification shall be one of the following forms, as necessary to ensure that all candidate fuels made to the specification would not cause greater emissions of the pollutants addressed by the protocol than would the test gasoline:

   (a) allowable value of property < [specified value]
   (b) allowable value of property > [specified value]
   (c) [specified value] < property < [specified value]

3. the engine families, model years, California or U.S. certification, and sources of vehicles with which the applicant proposes to satisfy subsection V.B. (if the option in subsection V.B.7 is not exercised);

4. if the option in subsection V.B.7 is exercised, the method by which random sampling will be accomplished;

5. the identities of any contractors who will conduct emission tests or analyses of samples;

6. quality control provisions consistent with good laboratory procedures in testing for the emission levels expected to be encountered in the tests,

7. the number of emission tests (duplicates and replicates) to be run on each vehicle within each vehicle category,

8. an approximate description of the test fuel, including all properties described in subsection VI.A.1.,

9. a test procedure for determining the value of each property described in VI.A.1 that does not have an adopted gasoline specification, and

10. a description of any statistical test by which the applicant would analyze individual test data to identify and discard statistical outliers.

B. Items 1. and 2. below apply to each proposed specification that would alter an adopted gasoline specification or that pertains to a gasoline property that does not have an adopted gasoline specification.

1. If a specification is of the kind in subsection VI.A.2.(a) or (b), the value of [specified value] shall be the value measured for that property in the test fuel, as described in subsection VI.E.

2. If a specification is of the kind in subsection VI.A.2.(c), the values of [specified value] shall be stated in the test plan.

C. For each adopted gasoline specification that would not be changed by the proposed alternative specifications, the value of the associated property in the test fuel shall satisfy that specification and be typical of values in current retail gasoline.

D. Unless the option in subsection V.B.7 is exercised, after the executive officer's approval of the plan, the applicant shall specify to the executive officer the vehicle identification numbers of the vehicles to be tested. These numbers shall become part of the approved plan.

E. After the executive officer's approval of the plan, the applicant shall supply measurements of the properties of the test fuel, including all properties described in subsection VI.A.1.

F. No datum shall be considered valid for the purpose of a demonstration controlled by this protocol unless that datum has been produced according to a plan approved by the executive officer before the datum has been taken.

G. Except as provided by section VIII., no demonstration shall be valid unless all data corresponding to an approved plan have been taken and included in the calculations prescribed in section IX.

H. Except as provided by section VIII., deviations from an approved plan shall not be permitted except by the prior permission of the executive officer.

I. No more than 20 days after receiving a proposed test plan, the executive officer shall either inform the applicant that the plan is complete or advise the applicant of necessary additions or changes. No more than 15 working days after receiving requested additions or changes, the executive officer shall advise the applicant that the amended plan is complete or further advise the applicant of necessary additions or changes. No more than

20 working days after advising the applicant that a plan is complete, the executive officer shall either approve or reject the plan. A rejection shall be accompanied by specifications of deficiencies.

J. The executive officer shall not approve a test plan unless he or she finds that it would produce a valid emission demonstration, as required by section II, by the procedures described in this protocol.

K. If requested by the executive officer, the applicant shall supply a sample of the test fuel to the ARB.

VII. EMISSION TEST PROCEDURES

A. All emission tests shall be done according to "California Exhaust Emission Standards and Test Procedures for ~~1988~~ 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles," incorporated by reference in ~~T~~title 13, California Code of Regulations, section ~~1960.1~~ 1961(d).

[Commentary: The Test Procedure reference is updated to reflect the new test procedures adopted as part of the LEV II/ CAP 2000 rulemaking.]

B. Within any vehicle category, the same number of replicate tests and the same number of duplicate tests within each replicate test shall be run on each test vehicle on both the reference fuel and the test fuel. The number of replicate tests and the number of duplicate tests shall be determined by the applicant (subject to approval as part of the test plan) and may vary among the vehicle categories.

C. The first fuel to be tested in any vehicle shall be chosen randomly.

D. Whenever the fuel to be tested in a vehicle differs from the existing fuel in the vehicle, and whenever a replicate test is to be run, the test vehicle's fuel tank and fuel delivery system shall be drained of fuel to the extent that is practicable. The fuel tank shall then receive a 40 percent fill of the fuel to be tested. The vehicle shall then be run through one Highway Fuel Economy Driving Cycle (HFEDC) (40 Code of Federal Regulations, Part 600, Subpart B). The fuel tank and fuel delivery system shall again be drained, and the tank shall receive a 40 percent fill of the test fuel. Finally, the vehicle shall undergo another HFEDC and two consecutive LA4 cycles. The test vehicle shall not be operated again before the tests required in A. above.

E. Pre-testing procedures alternative to subsection VII.D. may be used if they are part of the approved plan described in section VI. Such alternatives may be approved only if found to be equivalent or superior in achieving a valid test of the fuel under test.

F. In each FTP test run, the NMOG emissions shall be speciated for determining the ozone-forming potential of the vehicle's exhaust. Species in the NMOG emissions shall be

identified and quantified by the procedures in the "California Non-Methane Organic Gas Test Procedures". Exhaust emissions of benzene, 1-3 butadiene, formaldehyde, and acetaldehyde shall be identified and quantified using the procedures in the same document.

VIII. EXCLUSION OF DATA OR VEHICLES

A. Any datum from an individual test run may be excluded as an outlier relative to its duplicate data (or to its replicate data if replicates do not contain duplicate tests) if so indicated by a statistical test approved by the executive officer as part of the test plan. If an analysis is used to exclude one or more datum for a pollutant, the same analysis shall be applied to all data for that pollutant.

B. Any vehicle may be excluded from the test program if it cannot be tested safely. In such a case, a similar vehicle shall be tested.

C. No datum shall be used in an emission demonstration under this protocol if:

1. test procedures during the generation of the datum differed from the procedures required by VII.A., or

2. the datum was taken without adherence to the quality control requirements in the test plan, or

3. the vehicle used to generate the datum can be shown to have operated in a way different from the way it operated during other tests, and such a difference can reasonably be expected to affect emissions, or

4. either the testing equipment or the chemical analytical equipment can be shown to have functioned differently during the generation of the datum than during other tests, and such difference in function can reasonably be expected to affect emissions.

D. A datum deleted according to one of the disqualifying conditions in VIII.C. shall be replaced by a new test unless the vehicle used to generate the datum is no longer in the possession of the applicant or the applicant's contractor or unless the vehicle has been used in ordinary service since testing was completed. However, if the original vehicle cannot be tested and the deletion of a datum leaves no data for a particular vehicle/fuel combination, a similar vehicle shall be obtained and all tests on the original vehicle shall be repeated with the replacement vehicle.

IX. CALCULATIONS

A. Summary and Explanation of Calculations

This procedure calculates a statistical upper bound on the difference in average emissions per mile from the test fuel and from the reference fuel for the relevant on-road vehicle fleet. The emissions of all the pollutants measured during testing are expressed in units of mass per mile. The calculation procedure is the same for all pollutants.

From the data on each vehicle, the difference in average emissions per mile is calculated as:

average emissions per mile from the test fuel
minus
average emissions per mile from the reference fuel

where the average is over all data, whether duplicate test data or replicate test data.

Within each vehicle category, the difference in emissions between the two fuels is the mean value of the difference values among vehicles. Within each vehicle category, the standard deviation of the difference among vehicles is also calculated.

The expectation value of the relevant on-road vehicle fleet's average difference in emissions per mile is the weighted average of the differences in emissions among the vehicle categories. The weights used in the averaging are the estimates of total miles travelled by vehicles in the various categories.

Estimates of the standard error and degrees of freedom corresponding to the fleet-average difference in emissions are calculated from the weights, the numbers of test vehicles in the categories, and the standard deviations within categories.

The upper bound on the average difference in emissions for the on-road fleet is calculated from the expectation value, the standard error, and the one-sided student-t value for the 0.15 significance level and the calculated degrees of freedom.

The tolerance value for the upper bound is a tolerance fraction times the weighted average value of the average emissions measured within vehicle categories on the reference fuel.

The type of statistical upper bound computed by this procedure is called an "upper confidence limit" in the statistical literature. Upper confidence limits for a statistical result have a high probability of exceeding the unknown true value of the quantity being measured. The probability is approximately 85 percent that the (unknown) true value of the mileage-weighted average difference of emissions per mile is less than its corresponding upper confidence limit. Consequently, if the true value of the difference in average emissions per mile is greater than the tolerance value, approximately 85 percent,

or more, of all possible upper confidence limits will exceed this true value and therefore exceed the tolerance value. It follows that a candidate fuel with a true difference of emissions of a certain pollutant greater than the tolerance value will satisfy the criterion, and be accepted (with respect to that pollutant, only) as causing no increase in emissions, only about 15 percent of the time.

The upper confidence limits computed by this procedure are 85 percent one-sided upper confidence limits for a weighted average of normally distributed random variables. They are based on an approximate t-distribution. The degrees-of-freedom parameter of this distribution is calculated by Welch's approximation.

B. Test Run Results

1. Emission rates of CO, NOx, and NMOG, expressed as "g/mile", and the emission rate of each toxic pollutant, expressed as "mg/mile", shall be determined in each test by the procedure described in the "California Exhaust Emission Standards and Test Procedures for ~~1988~~ 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles," incorporated by reference in title 13, California Code of Regulations, section 1961(d), .

2. Values of ozone-forming potential, in "g ozone per mile", shall be determined for exhaust emissions in each test according to ~~Appendix VIII~~ Part II, Section D. of the ~~regulation stated~~ Standards and Test Procedures referred to in subsection IX.B.1.

[Commentary: The Test Procedure reference is updated to reflect the new test procedures adopted as part of the LEV II/ CAP 2000 rulemaking.]

3. In each test, the emission rate of each toxic pollutant shall be multiplied by its relative potency, as shown in the following table, and the four products shall be summed.

	Relative Potency
1,3-butadiene	1.0
benzene	.17
formaldehyde	.035
acetaldehyde	.016

C. Upper Confidence Limit for Inferred Mean Emission Difference

1. The procedures in this section shall be followed for the test fleet required by subsection VII.A. The procedures shall be followed separately by CO, NOx, NMOG, the combined ozone-forming potential of exhaust NMOG, and the combined potency-weighted toxic emissions.

2. For each vehicle, the results, (g/mile for CO, NOx, and NMOG, g ozone/mile, or mg/mile for combined potency-weighted toxic emissions) from all tests (whether

duplicates or replicates) on the test fuel shall be averaged, as shall the results from all tests on the reference fuel. The average result when the vehicle is tested on the reference fuel shall be subtracted from the average when the vehicle is tested on the test fuel. The result of the subtraction is a difference value for the vehicle, d_v for the pollutant measure.

3. Within each vehicle category, the mean value and squared standard deviation of mean difference values shall be calculated over all vehicles:

   $m_{d,i}$ = mean value of d_v over all (n_i) vehicles in category i

   $s^2_{d,i}$ = square of standard deviation corresponding to $m_{d,i}$

   = sum over vehicles of $\{(d_v - m_{d,i})^2 / (n_i - 1)\}$

4. The population-weighted mean value of m_d shall be calculated over all tested vehicle categories:

   D = Sum over all categories (i) of $\{m_{d,i} * p_i\}$

   where p_i is total miles travelled by on-road vehicles in vehicle category i divided by the sum of total miles travelled by on-road vehicles in all categories that have been tested within the fleet. The values of "p" shall be determined for the same time as the sums of NMOG emissions and the sums of miles travelled described in subsections V.A.3.

5. The standard error of the weighted mean emission difference shall be calculated from the standard deviations within emission categories:

   $S.E.^2$ = Sum over all categories (i) of $\{p^2_i * s^2_{d,i} / n_i\}$

   where n_i is the number of test vehicles in category i.

6. The number of degrees of freedom associated with D shall be calculated as:

$$nu = \frac{(S.E.^2)^2}{\text{Sum over all categories of } \{p^4_i * s^4_{d,i} / [n^2_i * (n_i - 1)]\}}$$

7. The upper confidence limit for the population mean emission difference shall be calculated as:

   $UCL = D + t_{.15,\,nu} * S.E.$

   where t is the one-tailed "student's t" value for significance level (alpha) = .15 and degrees of freedom nu.

8. "t" shall be calculated as:

$$t_{.15,\,nu} = U + (U^3 + U)/(4 * nu) + (5 * U^5 + 16 * U^3 + 3 * U)/(96 * nu)$$

where U = 1.036

D. Emissions from the Use of Reference Fuel

1. Within each test vehicle category, the average of all emission results (mass/mile) when the reference fuel is used, as described in IX.B.2, shall be averaged over all vehicles. The result, $e_{c,i}$, is the emission rate for category i.

2. The estimate of the on-road fleet emissions from the use reference fuel shall be the weighted sum over categories of $e_{c,i}$ using the same weights, p_i, as in the calculation of D.

$$E_c = \text{sum over all categories (i) of } \{p_i * e_{c,i}\}$$

X. SUBMISSION OF RESULTS

By means agreed upon by the executive officer and the applicant, the applicant shall submit documentation of adherence to the plan described in section VI. and to the procedures specified in section VII., the calculations required in section IX., any outlier analyses conducted per paragraph VIII.A., the output from all FTP runs and all specifications of NMOG.

XI. CERTIFICATION OF CANDIDATE FUELS

A. No more than 20 working days after receiving the information described in section X., the executive officer shall either inform the applicant that the information is complete or advise the applicant of necessary additions or changes. No more than 15 working days after receiving requested additions or changes, the executive officer shall advise the applicant that the amended information is complete or further advise the applicant of necessary additions or changes. No more than 20 working days after advising the applicant that the information is complete, the executive officer shall deem the demonstration required by section II., concerning emission comparisons, to be either accomplished or not accomplished. A rejection shall be accompanied by specifications of deficiencies.

B. If the executive officer determines that an applicant has accomplished the demonstration concerning emission comparisons in section II., the executive officer shall certify the candidate fuel as a Phase 2 CaRFG or Phase 3 CaRFG3 certified alternative gasoline formulation. The executive officer shall include in the certification order specifications

for properties of the certified fuel in accordance with subsections VI.A.I., VI.B., and VI.C. The executive officer shall notify interested parties of the certification order within 10 days of issuance.

C. A certification shall be in force for five years, at which time the reapproval process in section XII. shall be followed.

XII. PERIODIC REAPPROVAL

A. Every five years after the initial certification of alternative specifications, test data shall be provided for any vehicle category previously exempted from testing pursuant to section V.A.4. if the exempting criteria (less than 3 percent of emissions and less than 5 percent of miles travelled) are no longer met. Test data shall also be provided for any previously tested vehicle category for which the executive officer determines that the vehicles tested no longer provide a reasonable representation of the on-road vehicles in that category.

B. Every five years, the upper confidence limit specified in subsection IX.C. and the emissions from the use of reference fuel specified in subsection IX.D. shall be re-calculated for the test fleets identified in subsection V.A.4. The calculations shall use the original test data, any new test data provided pursuant to subsection XII.A. or XIII.A., and the current statistical weights (p) as described in subsection IX.C.4. If the upper confidence level exceeds the criterion in section IV. for any pollutant, the certification of the fuel shall be rescinded, effective two years following the date of the order rescinding the certification.

XIII. AUGMENTATION OF ORIGINAL TEST DATA

A. An applicant who made the petition that led to the approval may augment any portion of the information in the original test plan or the submission required in section X. All new information shall be developed according to this test protocol.

B. If new information or proposed changes are submitted, the executive officer shall evaluate and either accept or reject them by standards consistent with the requirements in this procedure for the original approval.

State of California
California Environmental Protection Agency
AIR RESOURCES BOARD

California Procedures for Evaluating Alternative Specifications for Phase 3 Reformulated Gasoline Using the California Predictive Model

Adopted: June 16, 2000
Amended: April 25, 2001
Amended: November 18, 2004
Last Amended: August 7, 2008

Table of Contents

Table of Contents (continued)

List of Tables

I. INTRODUCTION

A. Purpose and Applicability

1. The predictive model prescribed in this document may be used to evaluate gasoline specifications as alternatives to the Phase 3 California Reformulated Gasoline (RFG) flat and averaging limits in the gasoline specifications set forth in Title 13, California Code of Regulations (13 CCR), section 2262.

   This procedure:

   - prescribes the range of specifications that may be utilized to select a set of candidate Phase 3 RFG alternative gasoline specifications for evaluation,
   - defines the Phase 3 RFG reference specifications,
   - prescribes the calculations to be used to predict the emissions from the candidate fuel specifications and the reference Phase 3 RFG specifications,
   - prescribes the calculations to be used to compare the emissions resulting from the candidate fuel specifications to the reference Phase 3 RFG specifications,
   - establishes the requirements for the demonstration and approval of the candidate fuel specifications as an alternative Phase 3 RFG formulation, and
   - establishes the notification requirements.

2. Gasoline properties for which alternative gasoline specifications may be set by this procedure include all eight Phase 3 RFG properties.

3. The Phase 3 RFG specifications, established in 13 CCR, section 2262, are shown in Table 1.

4. The pollutant emissions addressed by these procedures and the units of model predictions are shown in Table 2.

Table 1
Properties and Specifications for Phase 3 Reformulated Gasoline

Fuel Property	Units	Flat Limit	Averaging Limit	Cap Limit
Reid vapor pressure (RVP)	psi, max.	6.90[1]/7.00	none	7.20
Sulfur (SUL)	ppmw, max.	20	15	60/30[3]/20[3]
Benzene (BENZ)	vol.%, max.	0.80/1.00[2]	0.70	1.10
Aromatic HC (AROM)	vol.%, max.	25.0/35.0[2]	22.0	35.0
Olefin (OLEF)	vol.%, max.	6.0	4.0	10.0
Oxygen (OXY)	wt. %	1.8 (min) 2.2 (max)	none	1.8(min)[4] 3.5(max)[5]
Temperature at 50 % distilled (T50)	deg. F, max.	213/220[2]	203	220
Temperature at 90% distilled (T90)	deg. F, max.	305/312[2]	295	330

[1] The flat limit for RVP is 7.00 psi. The flat limit for RVP is 6.90 when the fuel being certified is blended without ethanol. The Reid vapor pressure (RVP) standards apply only during the warmer weather months identified in section 2262.4.

[2] The higher value is the small refiner CaRFG flat limit for qualifying small refiners only, as specified in section 2272.

[3] The CaRFG Phase 3 sulfur content cap limits of 60, 30, and 20 parts per million are phased in starting December 31, 2003, December 31, 2005, and December 31, 2011, respectively, in accordance with section 2261(b)(1)(A).

[4] Applicable only during specified winter months in the areas identified in 13 CCR, section 2262.5(a).

[5] If the gasoline contains more than 3.5 percent by weight oxygen but not more than 10 volume percent ethanol, the maximum oxygen content cap is 3.7 percent by weight.

Table 2
Predictive Model Pollutants and Their Units of Measurement

Pollutant Predictions	Units
Oxides of Nitrogen (NOx)	gm/mile
Exhaust Hydrocarbons (HC)	gm/mile
Evaporative Hydrocarbons (HC)	Percent Change (Candidate Fuel Relative to Reference Fuel)
Exhaust Potency-Weighted Toxics (PWT)	mg/mile
Evaporative Benzene	mg/mile
Exhaust CO (Adjustment Factor for Oxygen)	gm/mile

B. Synopsis of Procedure

The predictive model is used to predict the emissions for gasoline meeting the Phase 3 RFG specifications (reference fuel specifications) and the emissions for a candidate gasoline meeting alternative specifications (candidate fuel specifications). The predicted emissions are functions of the regulated fuel properties shown in Table 1. The candidate gasoline is accepted as equivalent to Phase 3 RFG if its predicted emissions for each pollutant is less than or equal (within roundoff) to the predicted emissions for a fuel meeting the Phase 3 RFG specifications.

1. What is the Predictive Model?

The predictive model consists of a number of sub-models. The sub-models are equations which relate gasoline properties to the exhaust emissions and evaporative emissions changes which result when the gasoline is used to fuel a motor vehicle. The emissions predictions are expressed in the units shown in Table 2.

Twenty-one separate exhaust sub-models have been developed for seven pollutants (NOx, HC, CO, benzene, 1,3-butadiene, formaldehyde, and acetaldehyde). Three exhaust sub-models have been developed for each of the seven pollutants: one sub-model for each of three vehicle emissions control technology "Tech" classes (Tech 3, Tech 4, and Tech 5).

In addition, six sub-models have been developed for evaporative emissions. Three sub-models have been developed for evaporative hydrocarbon emissions and three sub-models have been developed for evaporative benzene emissions. For both evaporative hydrocarbon emissions and evaporative benzene emissions, one sub-model has been

developed for each of the following evaporative emission processes:
1) Diurnal/Resting Losses, 2) Hot Soak Emissions, and 3) Running Losses. Finally, an adjustment factor has been developed to predict the effect of changing fuel properties on exhaust CO emissions.

2. Combination of Sub-Model Predictions for Exhaust Emissions Across Tech Classes

The exhaust emissions of the reference fuel specifications and the candidate fuel specifications for each Tech class of vehicles are predicted by the sub-models of the predictive model. The differences between the predicted exhaust emissions for the reference fuel specifications and the candidate fuel specifications are combined to yield Tech class-weighted predicted emissions differences. These predicted differences represent the predicted differences in exhaust emissions between the reference fuel specifications and the candidate fuel specifications for the entire California vehicle fleet. For NOx and exhaust HC emissions, the differences in predictions for each Tech class are combined using Tech class weighting factors which represent the fraction of the total emissions originating from each Tech class.

For the exhaust toxics emissions, the predicted emissions for Tech classes are weighted both by fractions and by potencies. The potency weights represent the relative carcinogenicity of the toxic pollutants. For each toxic pollutant, the predicted exhaust emissions for each Tech class is weighted by the HC exhaust Tech group weighting factor which represents the fraction of the total vehicle miles traveled by each Tech class. Then, the Tech class-weighted emissions prediction for each toxic pollutant is multiplied by the relative potency for that pollutant. The Tech class-weighted, potency-weighted predictions for each toxic pollutant are then summed to yield the predicted total potency-weighted exhaust toxics emissions. Finally, an emissions prediction for evaporative benzene emissions is added to the prediction for total potency-weighted exhaust toxics emissions to yield a prediction for total potency-weighted toxics emissions. This calculation is performed for both the reference fuel specifications and the candidate fuel specifications.

3. Combination of Evaporative HC Emissions Predictions with Exhaust HC Emissions Predictions (Optional)

Two compliance options are available to applicants. The first compliance option includes predictions for differences in evaporative HC emissions between the candidate fuel specifications and the Phase 3 RFG reference fuel in the evaluation of the HC emissions equivalency of the candidate fuel. The second option does not, and the HC emissions equivalency of the candidate fuel specifications is based only on the predictions of the exhaust HC emissions models, as is the case in the Phase 2 RFG regulations. In the first compliance option, the Tech class-weighted difference in the predicted exhaust HC emissions between the reference fuel specifications and the candidate fuel specifications is combined with the predicted difference in evaporative HC emissions between the two fuels when evaluating the HC emissions equivalency of the candidate fuel specifications. This combination estimates the difference in total HC emissions (exhaust plus evaporative) between the reference fuel specifications and the candidate fuel specifications. In the second compliance option, the predicted evaporative HC emissions changes are not

included and the HC emissions equivalency of the candidate fuel specifications is based only on the Tech class-weighted difference in the predicted exhaust HC emissions. This was the only compliance option available in the Phase 2 RFG regulations. The second option is being offered for applicants who are not interested in using the evaporative HC emissions model in the evaluation of the HC emissions equivalency of the alternative fuel specifications.

Under the first compliance option, when combining the Tech class-weighted difference in the predicted exhaust HC emissions with the predicted difference in evaporative HC emissions, the greater ozone-forming potential of the exhaust emissions is recognized by the inclusion of a "reactivity adjustment" factor for the evaporative HC emissions. Also, the ozone-forming potential of CO emissions is recognized in this compliance option by the inclusion of emissions in the sum of exhaust and evaporative HC emissions. Thus, under this compliance option, the combination of the model predictions for exhaust HC emissions, evaporative HC emissions changes, and CO emissions yields a number which represents a prediction for the change in ozone-forming potential (OFP) between the reference fuel specifications and the candidate fuel specifications. The flat and cap RVP limits for this compliance option are 7.00 psi, and 7.20 psi, respectively for fuels containing ethanol, and flat and cap RVP limits of 6.90 and 7.20 psi, respectively for fuels not containing ethanol.

Under the second compliance option, only the Tech class-weighted difference in the predicted exhaust HC emissions is used in comparing the HC emissions of the reference fuel specifications to the HC emissions of the candidate fuel specifications. Under this option, evaporative HC emissions of the candidate fuel are limited by the imposition of a flat (and cap) RVP limit of 7.0. The CO adjustment factor also is not used under the second compliance option.

Either the first or second compliance options can be used during the RVP control season until December 31, 2009. Beginning December 31, 2009, only the first compliance option can be used during the RVP control season. Only the second compliance option can be used outside of the RVP control season.

4. Determination of Emissions Equivalency

The candidate fuel specifications are deemed equivalent to the reference fuel specifications if, for each pollutant (NOx, total OFP or exhaust HC, and potency-weighted toxics (PWT)), the predicted percent change in emissions between the candidate fuel specifications and the reference Phase 3 RFG specifications is equal to or less than 0.04%. If the applicant has elected to use the evaporative HC emissions model in the evaluation of the emissions equivalency, the 0.04% criteria must be met for NOx, OFP, and PWT. If the applicant has elected not to use the evaporative HC emissions model, the 0.04% criteria must be met for NOx, exhaust HC, and PWT. If, for any of the three pollutants in the criteria, the predicted percent change in emissions between the candidate fuel specifications and the reference Phase 3 RFG specifications is equal to or greater than 0.05%, the candidate specifications are deemed unacceptable and may not be a substitute for Phase 3 RFG. [Note: All final values of the percent change in emissions shall be

reported to the nearest hundredth using conventional rounding.]

C. Definitions

1. **Alternative gasoline formulation** means a final blend of gasoline that is subject to a set of alternative specifications deemed acceptable pursuant to the California Procedures for Evaluating Alternative Specifications for Phase 3 Reformulated Gasoline Using the California Predictive Model.

2. **Alternative fuel specifications** means the specifications for the following gasoline properties, as determined in accordance with 13 CCR, section 2263:
   - maximum Reid vapor pressure, expressed in the nearest hundredth of a pound per square inch;
   - maximum sulfur content, expressed in the nearest parts per million by weight;
   - maximum benzene content, expressed in the nearest hundredth of a percent by volume;
   - maximum olefin content, expressed in the nearest tenth of a percent by volume;
   - minimum and maximum oxygen content, expressed in the nearest tenth of a percent by weight;
   - maximum T50, expressed in the nearest degree Fahrenheit;
   - maximum T90, expressed in the nearest degree Fahrenheit; and
   - maximum aromatic hydrocarbon content, expressed in the nearest tenth of a percent by volume.

3. **Applicant** means the party seeking approval of alternative gasoline specifications and responsible for the demonstration described herein.

4. **Aromatic hydrocarbon content (Aromatic HC, AROM)** means the amount of aromatic hydrocarbons in the fuel expressed to the nearest tenth of a percent by volume in accordance with 13 CCR, section 2263.

5. **ASTM** means the American Society of Testing and Materials.

6. **Averaging Limit** means a limit for a fuel property that must be achieved in accordance with 13 CCR, section 2264.

7. **Benzene content (BENZ or Benz)** means the amount of benzene contained in the fuel expressed to the nearest hundredth of a percent by volume in accordance with 13 CCR, section 2263.

8. **Candidate fuel or candidate fuel specifications** means the fuel or set of specifications which are being evaluated for its emission performance using these procedures.

9. **Cap limit** means a limit that applies to all California gasoline throughout the gasoline distribution system, in accordance with 13 CCR, sections 2262.3 (a), 2262.4 (a), and 2262.5 (a) and (b).

10. **EMFAC2007** means the EMFAC2007 motor vehicle emission inventory and emissions calculation system maintained by the ARB.

11. **Ethanol content** means the amount of ethanol in the fuel expressed to the nearest tenth of a percent by volume.

12. **Executive Officer** means the executive officer of the Air Resources Board, or his or her designee.

13. **Exhaust-only option** means the compliance option available to applicants which uses only the exhaust HC emissions models in the evaluation of the HC emissions equivalency of the candidate fuel specifications.

14. **Evap option** means the compliance option available to applicants which uses the evaporative HC emissions models and the CO adjustment factor in the evaluation of the HC emissions equivalency of the candidate fuel specifications.

15. **Flat limit** means a single limit for a fuel property that applies to all California gasoline sold or supplied from a California production facility or import facility.

16. **Intercept** means the average vehicle effect for a particular Tech class and a particular pollutant. The intercept represents the average emissions across vehicles in the Tech class, for a fuel with properties equal to the average values of all fuels in the data base for that Tech class.

17. **MTBE content (MTBE)** means the amount of methyl tertiary-butyl ether in the fuel expressed in the nearest tenth of a percent by volume.

18. **Olefin content (OLEF)** means the amount of olefins in the fuel expressed in the nearest tenth of a percent by volume in accordance with 13 CCR, section 2263.

19. **Oxygen content (OXY)** means the amount of oxygen contained in the fuel expressed in the nearest tenth of a percent by weight in accordance with 13 CCR, section 2263.

20. **Phase 3 reformulated gasoline (Phase 3 RFG)** means gasoline meeting the flat or averaging limits of the Phase 3 RFG regulations.

21. **Potency-weighted exhaust toxics (PWT)** means the mass exhaust emissions of benzene, 1,3-butadiene, formaldehyde, and acetaldehyde multiplied by the relative potency with respect to 1,3-butadiene.

22. **Predictive model** means a set of equations that relate the properties of a particular gasoline formulation to the predicted exhaust and evaporative emissions that result when that gasoline is combusted in a motor vehicle engine.

23. **Reference fuel or reference fuel specifications** means a gasoline meeting the flat or average specifications for Phase 3 RFG.

24. **Reid vapor pressure (RVP)** means the vapor pressure of the fuel expressed in the nearest hundredth of a pound per square inch in accordance with 13 CCR, section 2263.

25. **Sulfur content (SUL)** means the amount of sulfur contained in the fuel expressed in the nearest part per million in accordance with 13 CCR, section 2263.

26. **Technology class (Tech 3, Tech 4, and Tech 5)** means a classification of vehicles by model year based on the type of technology used to control gasoline exhaust emissions.

27. **50% distillation temperature (T50)** means the temperature at which 50% of the fuel evaporates expressed in the nearest degree Fahrenheit in accordance with 13 CCR, section 2263.

28. **90% distillation temperature (T90)** means the temperature at which 90% of the fuel evaporates expressed in the nearest degree Fahrenheit in accordance with 13 CCR, section 2263.

29. **Total potency-weighted toxics (PWT)** means the sum of the mass exhaust emissions of benzene, 1,3-butadiene, formaldehyde, and acetaldehyde, and the evaporative benzene emissions, multiplied by the relative potency with respect to 1,3-butadiene.

30. **Toxic air contaminants** means exhaust emissions of benzene, 1,3-butadiene, formaldehyde, and acetaldehyde, and evaporative benzene emissions.

II. VEHICLE TECHNOLOGY CLASS AND WEIGHTING FACTORS

A. Vehicle Technology Groups

For the purpose of these procedures, exhaust sub-models been developed for three categories of light-duty vehicles (passenger cars and light-duty trucks) using the vehicle model year as an indicator of the type of emission controls used. Table 3 shows the three vehicle categories.

Table 3
Vehicle Categories

Technology Class	Model Year	Emission Controls
Tech 3	1981-1985	older closed-loop three-way catalyst
Tech 4	1986-1995	closed-loop three-way catalyst
Tech 5	1996-2015	three-way catalyst, adaptive learning, LEVs

B. Emission-Weighting Factors

Emission-weighting factors are used, for NO_x, exhaust HC, and CO emissions, to weight the model predictions for each technology class. These weightings represent, for each of the three pollutants, the fractional contribution of exhaust emissions from on-road gasoline-fueled vehicles in a particular Tech class to the total emissions from these vehicles from all three Tech classes in the year 2015. The year 2015 was selected because it approximately represents the midpoint year over which the Phase 3 reformulated gasoline regulations will be most effective. The factors were calculated using the information in EMFAC2007. The emission-weighting factors (EWF) are shown in Table 4 and are used in the combination of the sub-models for NO_x, exhaust HC, and CO emissions.

Table 4
Emissions-Weighting Factors

Pollutant	Tech 3	Tech 4	Tech 5
NOx	0.052	0.325	0.622
HC	0.075	0.380	0.546
CO	0.063	0.288	0.649

C. Toxics Weighting Factors

Since toxics emissions are also exhaust HC, the hydrocarbon weighting factors are used to weight the model predictions for each technology class. The values were calculated for the year 2015 using the ARB's EMFAC2007 motor vehicle emissions inventory. The toxics weighting factors (TWFs) are shown in Table 5 and are used in the combination of the exhaust toxics emissions sub-models.

Table 5
Toxics Weighting Factors (TWFs)

Pollutant	Tech 3	Tech 4	Tech 5
Benzene	0.075	0.380	0.546
1,3-Butadiene	0.075	0.380	0.546
Formaldehyde	0.075	0.380	0.546
Acetaldehyde	0.075	0.380	0.546

III. GENERAL EQUATIONS FOR CALCULATING PERCENT CHANGES IN EMISSIONS

A. Summary and Explanation

- The applicant will first select one of two compliance options. The first compliance option, referred to as the exhaust and evap model option, uses the exhaust HC emissions models, the evaporative HC emissions changes models, and the CO adjustment in determining the HC emissions equivalency of the candidate fuel specifications based on ozone forming potential. The second option, referred to as the exhaust-only option, is set to sunset December 31, 2009 and uses only the exhaust HC emissions model in the determination of the HC emissions equivalency of the candidate fuel specifications. (See III.B)

  The exhaust and evap model option may only be used for final blends of California gasoline or CARBOB where some part of the final blend is physically transferred from its production or import facility during the Reid vapor pressure control period for the production or import facility set forth in section 2262.4, title 13, California Code of Regulations, or within 15 days before the start of such period.

- The applicant will select a candidate specification for each property, and will identify whether the specification represents a flat limit or an averaging limit. The Phase 3 RFG reference specification is identified for each property using the flat/average limit compliance option selected for the corresponding candidate specification. (See III.B.)

- The selected candidate specifications and the comparable Phase 3 RFG reference specifications are inserted into the predictive model equations to determine the predicted candidate and reference emissions by Tech class. (See III.C.)

- Because oxygen is specified in the form of a range, emissions predictions are, in a majority of the cases, made for two oxygen levels, the upper level of the specified range for the candidate fuel specifications and the lower level. The emissions of the candidate fuel are compared to the emissions of the reference fuel at both of these oxygen levels. When the range between the upper and lower oxygen levels is less than or equal to 0.4 percent then the prediction is only made for two oxygen levels. If the range is greater than 0.4 percent, then the prediction is based on the individual upper and lower levels.

- For NOx and exhaust HC, the ratio of the predicted emissions for the candidate fuel specifications to the predicted emissions for the reference fuel specifications is emissions weighted according to the relative contribution of each technology class. These emissions-weighted ratios are summed,

reduced by 1, and multiplied by 100 to represent the Tech class-weighted percent change in emissions. The resulting values represent the predicted percent change in NOx or exhaust HC emissions between the candidate fuel specifications and reference fuel specifications. (See III.D.)

- If the exhaust and evap model option has been selected, the predicted percent change in evaporative HC emissions between the candidate fuel specifications and the reference fuel specifications is computed using the equations given in Section VII*I*.A. The predicted change is computed for each evaporative emissions process. (See VII*I*.A)

- If the exhaust and evap model option has been selected, the CO emissions a calculated in accordance with the equations given in Section VI.A. (See VI.A)

- If the exhaust and evap model option has been selected, the predicted percent changes in exhaust HC emissions, evaporative HC emissions, and the CO emissions are combined in accordance with the equation given in Section X to yield the predicted percent change in ozone-forming potential (OFP) between the reference fuel specifications and the candidate fuel specifications. (See X)

- For exhaust toxics emissions, the predicted emissions for the candidate fuel specifications and the reference fuel specifications (for each pollutant and each Tech class) are weighted using the toxics weighting factors and potency-weighted, in accordance with the equations given in VII.B. (See VII.B)

- The evaporative benzene emissions predictions for the reference fuel specifications and the candidate fuel specifications are calculated in accordance with the equations given in Section IX.A. Note that emissions predictions for evaporative benzene emissions are made even if the applicant is not using the compliance option which provides for the use of the evaporative HC emissions models. (See IX.A)

- For both the reference fuel specifications and the candidate fuel specifications, the potency-weighted exhaust toxics emissions predictions are combined with the potency-weighted evaporative benzene emissions predictions, in accordance with the equations given in Sections XI.A and XI.B. This yields the total potency-weighted toxics emissions prediction for the reference fuel specifications and for the candidate fuel specifications. (See XI.A and XI.B)

- The percent change in the predicted total potency-weighted toxics emissions between the reference fuel specifications and the candidate fuel specifications is calculated in accordance with the equation given in Section XI.C. (See XI.C)

B. Selection by Applicant of Candidate and Reference Specifications

Before December 31, 2009, the applicant shall first select one of two compliance options. The first compliance option uses the exhaust HC emissions models, the evaporative HC emissions models, and the CO emissions model in determining the HC emissions equivalency of the candidate fuel specifications. The second option uses only the exhaust HC emissions model in the determination of the HC emissions equivalency of the candidate fuel specifications. After December 31, 2009, the second compliance option sunsets and the first compliance option that uses the exhaust HC emissions models, the evaporative HC emissions models, and the CO emissions model in determining the HC emissions equivalency of the candidate fuel specifications becomes the only compliance option during the RVP control season.

If the applicant selects the first compliance option, the applicable Phase 3 RVP limits are a flat limit of 7.00 and a cap limit of 7.20. That is, if the applicant elects to use the evaporative HC emissions predictive model, all evaporative HC emissions changes predicted by the model for the candidate fuel will be based on the use of 7.00 psi as the RVP of the Phase 3 reference fuel. If the applicant selects the second compliance option, the applicable Phase 3 RVP limit is a flat (and cap) limit of 7.00. If the applicant selects to certify an alternative formulation produced without ethanol, then the applicable flat limit for either compliance option is 6.90 psi RVP.

Next, the applicant shall, for each fuel property, select a candidate specification and indicate whether this specification represents a flat limit or an averaging limit. The appropriate corresponding Phase 3 RFG reference specifications (flat or average) are then identified. Table 7 provides an optional worksheet to assist the applicant in selecting the candidate and reference specifications. These steps are summarized below.

1. Identify the value of the candidate specification for each fuel property and insert the values into Table 7. The candidate specifications may have any value for RVP, sulfur, benzene, aromatic hydrocarbons, olefins, T50, and T90 as long as each specification is less than or equal to the cap limits shown in Table 1. Note that, if the applicant is not using the compliance option which provides for the use of the evaporative HC emissions models, no value is entered for RVP into the "Candidate Fuel Specifications" column of Table 7 (In this case the RVP is 7.00). The candidate specification may have any value for oxygen as long as the specification is within the range of the cap limits shown in Table 1.

2. When the range between the upper and lower oxygen levels is less than or equal to 0.4 percent, then the prediction is only made for the average of the two oxygen levels. If the range is greater than 0.4 percent, then the prediction is based on the individual upper and lower levels. If the range between the upper and lower oxygen levels is greater than 0.4 percent, then the oxygen contents of the reference fuel specifications can be found from

Table 6. Since oxygen is specified in the form of a range, there are usually two candidate fuel specifications for oxygen, the upper end of the range (maximum) and the lower end of the range (minimum).

3. The hot soak benzene emissions model contains a MTBE content term. The relevant oxygen content value is the oxygen content as MTBE, not the total oxygen content as in the case of the exhaust emissions predictions. The result is that, if the candidate fuel does not contain MTBE, the oxygen content as MTBE for the reference fuel is 2.0 percent, and the oxygen content as MTBE for the candidate fuel is zero percent. The reason it is assumed that the reference fuel contains MTBE is that MTBE was the oxygenate used while the Phase 2 regulations were in effect, and this assumption helps ensure that potency-weighted toxics emissions from Phase 3 gasoline will not be greater than those from Phase 2 gasoline.

4. For each property other than oxygen and RVP, indicate whether the candidate specification will represent a flat limit or an averaging limit.

5. For each candidate specification identified in 1., identify the appropriate corresponding Phase 3 RFG reference specifications (flat or average). Circle the appropriate flat or average limit for the reference fuel in Table 7. The circled values are the reference specifications which will be used in the predictive model.

   When the range between the upper and lower oxygen levels is less than or equal to 0.4 percent, then the oxygen level of the reference fuel is 2.0 wt%. If the range is greater than 0.4 percent, then Table 6 gives the oxygen contents of the reference fuel specifications. Because oxygen is specified in the form of a range, there are two reference fuel oxygen specifications. In most cases they are the same, but in two cases they are not. These two cases are: 1) If the minimum oxygen content of the candidate fuel specifications is within 1.8 to 2.2 percent (inclusive) and the maximum oxygen content of the candidate is greater than 2.2 percent, and 2) If the minimum oxygen content of the candidate fuel specifications is less than 1.8 percent and the maximum oxygen content of the candidate is between 1.8 and 2.2 percent (inclusive). In case 1), the oxygen contents of the reference fuel specifications are 1.8 and 2.0 percent. In case 2), the oxygen contents of the reference fuel specifications are 2.0 and 2.2 percent. (See Table 6)

Table 6
Candidate and Reference Specifications for Oxygen

Oxygen Content for Candidate Fuel Specified by Applicant		Number of Reference vs Candidate Comparisons Required	Values to be Used in Comparison in Equations	
Minimum	maximum		Candidate	Reference
> 1.8, < 2.2	> 2.2	2	minimum	1.8
			maximum	2.0
< 1.8	> 1.8, < 2.2	2	minimum	2.0
			maximum	2.2
< 1.8	> 2.2	2	minimum	2.0
			maximum	2.0
< 1.8	< 1.8	2	minimum	2.0
			maximum	2.0
> 2.2, < 2.5	> 2.2	2	maximum	2.0
			minimum	2.0
> 2.5	> 2.9	2	minimum	2.0
			maximum	2.0

Table 7
Optional Worksheet for Candidate and Reference Fuel Specifications

Does the applicant which to use the evaporative HC emissions model and the CO adjustment factor in the evaluation of the equivalency of the candidate fuel specifications? YES ___ NO ___

If the above question is answered yes, the reference fuel flat RVP limit is 7.00 psi and the RVP cap is 7.20 psi, unless the gasoline does not contain ethanol in which case the reference fuel flat RVP limit is 6.90 psi and the RVP cap is 7.20 psi. If the above question is answered no, 7.00 psi is the flat RVP limit and the candidate fuel RVP specification.

Fuel Property	Candidate Fuel[1]: Specifications	Compliance Option: Flat or Average	Reference Fuel: Phase 3 RFG Specifications (Circle Option Chosen)	
			Flat	Average
RVP		Flat	7.00[5] / 6.90[5]	None
Sulfur			20	15
Benzene			0.80/1.00[6]	0.70
Aromatic			25.0/35.0[6]	22.0
Olefin			6.0	4.0
Oxygen[2] (Total)	(min) (max)	Flat-Range	(min) (max)	None
Oxygen[3] (as MTBE)	(min) (max)	Not Applicable	Not Applicable	None
Oxygen[4] (as EtOH)	(min) (max)	Not Applicable	Not Applicable	None
T50			213/220[6]	203
T90			305/312[6]	295

Note: Footnotes are on the next page

Footnotes for Table 7

1 The fuel property value must be within or equal to the cap limit.

2 When the range between the upper and lower oxygen levels is less than or equal to 0.4 percent, then the prediction for the candidate fuel is only made for the average of the two oxygen levels, and the reference fuel oxygen value is 2.0. If the range is greater than 0.4 percent, then the prediction for the candidate fuel is based on the individual upper and lower levels, and the reference fuel oxygen value is obtained from Table 6.

3 The oxygen content (as MTBE) is reported because the hot soak evaporative benzene emissions model includes an MTBE content term (See VIII.A.2).

4 The oxygen content (as EtOH) is reported because the exhaust formaldehyde and the exhaust acetaldehyde models include EtOH content terms for the predictions for the candidate fuel specifications (See VI.A.1.c & d., VI.A.2.c & d., VI.A.3.c & d.). The EtOH content term is not included in the exhaust formaldehyde and acetaldehyde predictions for the reference fuel specifications because it is assumed that, for the reference fuel specifications, MTBE is the oxygenate used to meet the oxygen requirement.

5 If the applicant elects to certify an alternative formulation without theuse of ethanol, then the appropriate flat limit will be 6.90 psi; otherwise, the flat limit for RVP is 7.00 psi.

6 The higher value is the small refiner CaRFG flat limit for qualifying small refiners only, as specified in section 2272.

C. General Equations for Calculating Exhaust Emissions by Pollutant and by Technology Class

The selected candidate specifications and set reference specifications are inserted into the predictive model equations to determine the predicted pollutant emissions generated from each fuel formulation by Tech Class. The following is the general form of the equations used to calculate exhaust emissions of the candidate and reference fuel specifications for each pollutant and for each technology class.

$ln\ y_{Tech}$ = intercept + Σ [(fuel effects coefficient) x (standardized fuel property)]

or

y_{Tech} = Exp {intercept + Σ [(fuel effects coefficient) x (standardized fuel property)]}

where

ln is the natural logarithm.

Exp is the exponential.

y_{Tech} is the exhaust emission prediction in grams per mile (for NOx, HC, and CO), and milligrams per mile (for benzene, 1,3-butadiene, formaldehyde, and acetaldehyde) for a particular technology class. (Note: $y_{Tech\text{-}REF}$ is the emissions prediction for the reference fuel specifications and $y_{Tech\text{-}CAND}$ is the emissions prediction for the candidate fuel specifications.)

intercept represents the average vehicle effect for a particular Tech class and a particular pollutant. The intercepts are provided in Table 13, Coefficients for NOx, Exhaust HC, and CO Equations, and Table 14, Coefficients for Toxics Equations.

fuel effects coefficient represents the average fuel effects across all vehicles in the database for a particular Tech class and a particular pollutant. The fuel effect coefficients are provided in Table 13, Coefficients for NOx, Exhaust HC, *and CO* Equations, and Table 14, Coefficients for Exhaust Toxics Equations.

standardized fuel property is defined as:

standardized fuel property =

$$\frac{\text{[(actual fuel property) - (mean fuel value)]}}{\text{standard deviation of the value for the fuel property}}$$

actual fuel property represents the candidate or reference fuel property selected by the applicant in Table 7, Worksheet for Candidate and Reference Specifications.

Note that the actual fuel property may represent the minimum value of selected candidate fuel properties and is established by the linearization equations defined in sections IV. A. 2 & 3 and V. A. 2 & 3.

mean fuel value represents the average fuel values from all data that are used in developing the California Predictive Model. The mean and standard deviation are provided in Table 12, Standardization of Fuel Properties-Mean and Standard Deviation.

standard deviation of the value for the fuel property is the standard deviation from all data that are used in developing the California Predictive Model.

The equations include a term for the RVP effect, however, this term has been made a constant. This was done by computing the standardized RVP value at an actual RVP value of 7.0, and then multiplying this standardized RVP value by the RVP effect coefficient, thereby yielding an additional constant in the equations. Thus, the RVP term is shown as an additional constant (in addition to the intercept) in the exhaust emissions equations. This effectively removes from the exhaust models RVP as fuel property which effects exhaust emissions.

D. General Equations for Calculating Percent Change of Exhaust Emissions Between Candidate and Reference Specifications

To calculate the percent change of NOx, exhaust HC, and CO emissions, the ratio of the predicted emissions for the candidate specifications to the predicted emissions from reference specifications is multiplied by the technology class emission-weighting factors for NOx, HC, and CO. These weighted ratios are summed. The sum is reduced by 1 and multiplied by 100 to give the percent change in NOx, HC, and CO emissions.

The following is the general form of the equations used to calculate percent change in exhaust emissions between the candidate fuel specifications and the reference fuel specifications for each pollutant.

% Change in NOx, Exhaust HC, and CO Emissions:

%CE = percent change in emissions =

$$\{[(y_{\text{Tech 3-CAND}} / y_{\text{Tech 3-REF}}) \times EWF_{3q}] + [(y_{\text{Tech 4-CAND}} / y_{\text{Tech 4-REF}}) \times EWF_{4q}] + [(y_{\text{Tech 5-CAND}} / y_{\text{Tech 5-REF}}) \times EWF_{5q}]\} - 1\} \times 100$$

where

$y_{\text{Tech 3}}$, $y_{\text{Tech 4}}$, and $y_{\text{Tech 5}}$ are the pollutant emissions in grams per mile of a particular pollutant and particular Tech class,

$y_{\text{Tech-CAND}}$ is the emissions for the candidate specifications, and
$y_{\text{Tech-REF}}$ is the emissions for the reference specifications.

EWF_{3q}, EWF_{4q}, and EWF_{5q} are the technology class 3, technology class 4, and technology class 5 weighting factors for the particular pollutant q. The Vehicle Technology Class Weighting Factors are provided in Table 4.

E. General Equations for Calculating Percent Change of Exhaust Emissions Between Candidate and Reference Specifications

The total Tech class-weighted, potency-weighted exhaust toxics emissions is calculated as shown below.

$E_{\text{PWT-CAND}}$ = Exhaust PWT emissions for candidate specifications =

$$\sum\{[((y_{\text{Tech 3q-CAND}}) \times (TWF_3)) + ((y_{\text{Tech 4q-CAND}}) \times (TWF_4)) + ((y_{\text{Tech 5q-CAND}}) \times (TWF_5))] \times (PWF_q)\}$$

$E_{\text{PWT-REF}}$ = Exhaust PWT emissions for reference specifications =

$$\sum\{[((y_{\text{Tech 3q-REF}}) \times (TWF_3)) + ((y_{\text{Tech 4q-REF}}) \times (TWF_4)) + ((y_{\text{Tech 5q-REF}}) \times (TWF_5))] \times (PWF_q)\}$$

where

The summations are performed across the q number of toxics pollutants, that is: $(y_{Tech\ 3q})$, $(y_{Tech\ 4q})$, $(y_{Tech\ 5q})$ are the predicted emissions in milligrams per mile for each toxic air contaminant for Tech classes 3, 4, and 5.

$y_{Tech\text{-}CAND}$ is the emissions for the candidate fuel specifications, and
$y_{Tech\text{-}REF}$ is the emissions for the reference fuel specifications

TWF_3, TWF_4, TWF_5 are the toxics weighting factors for Tech classes 3, 4 and 5, respectively. These values are shown in Table 5.

PWF_q is the potency-weighting factor for each toxic air contaminant q provided in Table 8.

These equations are shown again in more detail in Section VII.B.1 for the candidate fuel specifications and Section VII.B.2 for the reference fuel specifications.

Table 8
Toxic Air Contaminant Potency-Weighting Factors

Pollutant	Potency-Weighting Factor
Benzene	0.170
1,3-Butadiene	1.000
Formaldehyde	0.035
Acetaldehyde	0.016

IV. OXIDES OF NITROGEN (NOx) EXHAUST EMISSIONS CALCULATIONS

A. NOx Emissions by Technology Class

The property values from the Table 7 worksheet are used to calculate NOx emissions for the candidate and reference specifications.

1. NOx Emissions for Tech 3

The NOx emissions for the candidate ($y_{\text{Tech 3-CAND}}$) and reference ($y_{\text{Tech 3-REF}}$) specifications for Tech 3 are calculated as follows:

NOx emissions Tech 3 = $y_{\text{Tech 3}}$ =

Description	Equation	
	Exp	
intercept	{-0.159800	+
RVP	(0.424915)	+
Sulfur	$(0.028040)\ \frac{(\text{SULFUR} - 139.691080)}{126.741459}$	+
Aromatic HC	$(0.047060)\ \frac{(\text{AROM} - 30.212969)}{8.682044}$	+
Olefin	$(0.021110)\ \frac{(\text{OLEF} - 7.359624)}{5.383804}$	+
Oxygen	$(0.014910)\ \frac{(\text{OXY} - 0.892363)}{1.235405}$	+
T50	$(-0.007360)\ \frac{(\text{T50} - 212.245188)}{15.880385}$	+
T90	$(0.000654)\ \frac{(\text{T90} - 312.121596)}{23.264684}$	}

where

SULFUR, AROM, OLEF, OXYGEN, T50, and T90 are the value limits for the candidate and reference specifications identified in the Table 7 worksheet.

2. NOx Emissions for Tech 4

The NOx emissions for the candidate ($y_{\text{Tech 4-CAND}}$) and reference ($y_{\text{Tech 4-REF}}$) specifications for Tech 4 are calculated as follows:

NOx emissions Tech 4 = $y_{\text{Tech 4}}$ =

Description	Equation	
	Exp	
intercept	{-0.634694	+
RVP	(-0.007046)	+
Sulfur	$(0.051043)\ \frac{(\text{SULFUR} - 154.120828)}{136.790450}$	+
Aromatic HC	$(0.011366)\ \frac{(\text{AROM} - 27.317137)}{6.880833}$	+
Olefin	$(0.017193)\ \frac{(\text{OLEF} - 6.549450)}{4.715345}$	+
Oxygen	$(0.028711)\ \frac{(\text{OXY} - 1.536017)}{1.248887}$	+
T50	$(-0.002431)\ \frac{(\text{T50} - 205.261051)}{17.324472}$	+
T90	$(0.002087)\ \frac{(\text{T90} - 310.931422)}{20.847425}$	+
T50T50	$(0.006268)\ \frac{(\text{T50} - 205.261051)}{17.324472}\ \frac{(\text{T50} - 205.261051)}{17.324472}$	+
T90ARO	$(-0.002892)\ \frac{(\text{T90} - 310.931422)}{20.847425}\ \frac{(\text{AROM} - 27.317137)}{6.880833}$	+
OXYOXY	$(0.010737)\ \frac{(\text{OXY} - 1.536017)}{1.248887}\ \frac{(\text{OXY} - 1.536017)}{1.248887}$	}

where

For calculating the reference fuel NOx emissions, SULFUR, AROM, OLEF, OXY, T50, and T90 are equal to the corresponding values for the reference specifications in the Table 7 worksheet.

For calculating candidate fuel NOx emissions, SULFUR, AROM, OLEF, OXY, and T90 are equal to the corresponding values for the candidate specifications in the Table 7 worksheet. The value for T50 is determined as follows:

If the value for the candidate T50 specification in the Table 7 worksheet is greater than 213 then 213 is the value for T50.

If the value for the candidate T50 specification in the Table 7 worksheet is less than or equal to 213, the T50 specification in the Table 7 worksheet is the value for T50.

3. NOx Emissions for Tech 5

The NOx emissions for the candidate ($y_{\text{Tech 5-CAND}}$) and reference ($y_{\text{Tech 5-REF}}$) specifications for Tech 5 are calculated as follows:

NOx emissions Tech 5 = $y_{\text{Tech 5}}$ =

Description	Equation	
	Exp	
intercept	{-1.599255	+
RVP	(-0.000533)	+
Sulfur	$(0.947915)\ \frac{(SULFUR - 144.6289001)}{140.912234}$	+
Aromatic HC	$(0.013671)\ \frac{(AROM - 26.875944)}{6.600312}$	+
Olefin	$(0.017335)\ \frac{(OLEF - 6.251891)}{4.431845}$	+
Oxygen	$(0.016036)\ \frac{(OXY - 1.551772)}{1.262823}$	+
T50	$(0.012397)\ \frac{(T50 - 206.020870)}{16.582090}$	+

$$
\begin{aligned}
&\text{T90} && (0.000762)\,\frac{(\text{T90} - 310.570200)}{22.967591} && + \\
&\text{T50T50} && (-0.022211)\,\frac{(\text{T50} - 206.020870)}{16.582090}\,\frac{(\text{T50} - 206.020870)}{16.582090} && + \\
&\text{T50OXY} && (-0.015564)\,\frac{(\text{T50} - 206.020870)}{16.582090}\,\frac{(\text{OXY} - 1.551772)}{1.262823} && + \\
&\text{OXYOXY} && (0.015199)\,\frac{(\text{OXY} - 1.551772)}{1.262823}\,\frac{(\text{OXY} - 1.551772)}{1.262823} && \Big\}
\end{aligned}
$$

where

For calculating the reference fuel NOx emissions, SULFUR, AROM, OLEF, OXY, T50, and T90 are equal to the corresponding values for the reference specifications in the Table 7 worksheet.

For calculating candidate fuel NOx emissions, SULFUR, AROM, OLEF, and T90 are equal to the corresponding values for the candidate specifications in the Table 7 worksheet. The value for OXY and T50 are determined as follows:

If the value of the candidate fuel Oxygen specification in the Table 7 worksheet is less than the $\text{OXYGEN}_{(\text{LIN})}$ value, then the $\text{OXYGEN}_{(\text{LIN})}$ value is the value for OXY, where $\text{OXYGEN}_{(\text{LIN})}$ is calculated as follows:

$$\text{OXYGEN}_{(\text{LIN})} = -7.148 + (0.039 \times \text{T50})$$

If the value for the candidate Oxygen specification in the Table 7 worksheet is greater than or equal to the $\text{OXYGEN}_{(\text{LIN})}$ value, then the Oxygen specification in the Table 7 worksheet is the value for OXY.

If the value of the candidate fuel T50 specification in the Table 7 worksheet is less than the $\text{T50}_{(\text{LIN})}$ value, then the $\text{T50}_{(\text{LIN})}$ value is the value for T50, where $\text{T50}_{(\text{LIN})}$ is calculated as follows:

$$\text{T50}_{(\text{LIN})} = 217.8 - (4.6 \times \text{OXY})$$

If the value for the candidate T50 specification in the Table 7 worksheet is greater than or equal to the $\text{T50}_{(\text{LIN})}$ value, then the T50 specification in the Table 7 worksheet is the value for T50.

B. Percent Change in NOx Emissions

The percent change in NOx emissions between the candidate specifications and the reference specifications is calculated as follows:

$$\%CE_{NOx}=\{\{[(y_{Tech\ 3\text{-}CAND} / y_{Tech\ 3\text{-}REF}) \times EWF_{3\text{-}NOx}] + [(y_{Tech\ 4\text{-}CAND} / y_{Tech\ 4\text{-}REF}) \times EWF_{4\text{-}NOx}] + [(y_{Tech\ 5\text{-}CAND} / y_{Tech\ 5\text{-}REF}) \times EWF_{5\text{-}NOx})]\} - 1\} \times 100$$

where

$y_{Tech\ 3\text{-}CAND}$, $y_{Tech\ 4\text{-}CAND}$, and $y_{Tech\ 5\text{-}CAND}$ are the NOx emissions for the candidate specifications in grams per mile for Tech 3, Tech 4, and Tech 5 respectively.

$y_{Tech\ 3\text{-}REF}$, $y_{Tech\ 4\text{-}REF}$, and $y_{Tech\ 5\text{-}REF}$ are the NOx emissions for the reference specifications in grams per mile for Tech 3, Tech 4, and Tech 5 respectively.

The NOx emissions for Tech 3 are calculated in accordance with the equations in section IV. A. 1.

The NOx emissions for Tech 4 are calculated in accordance with the equations in section IV. A. 2.

The NOx emissions for Tech 5 are calculated in accordance with the equations in section IV. A. 3.

$EWF_{3\text{-}NOx}$, $EWF_{-4\text{-}NOx}$, and $EWF_{-5\text{-}NOx}$ are the emission-weighting factors for NOx as shown in Table 4.

V. EXHAUST HYDROCARBONS (HC) EMISSIONS CALCULATIONS

A. Exhaust HC Emissions by Technology Class

The property values from the Table 7 worksheet are used to calculate HC emissions for the candidate and reference specifications.

1. Exhaust HC Emissions for Tech 3

The HC emissions for the candidate ($y_{\text{Tech 3-CAND}}$) and reference ($y_{\text{Tech 3-REF}}$) specifications for Tech 3 are calculated as follows:

HC emissions Tech 3 = $y_{\text{Tech 3}}$ =

Description	Equation	
	Exp	
intercept	{-0.752270	+
RVP	(0.000013)	+
Sulfur	$(0.038207)\left(\frac{\text{SULFUR} - 139.691080}{126.741459}\right)$	+
Aromatic HC	$(0.014103)\left(\frac{\text{AROM} - 30.212969}{8.682044}\right)$	+
Olefin	$(-0.016533)\left(\frac{\text{OLEF} - 7.359624}{5.383804}\right)$	+
Oxygen	$(-0.026365)\left(\frac{\text{OXY} - 0.892363}{1.235405}\right)$	+
T50	$(0.015847)\left(\frac{\text{T50} - 212.245188}{15.880385}\right)$	+
T90	$(0.011768)\left(\frac{\text{T90} - 312.121596}{23.264684}\right)$	+
T90ARO	$(0.016606)\left(\frac{\text{T90} - 312.121596}{23.264684}\right)\left(\frac{\text{AROM} - 30.212969}{8.682044}\right)$	+

T90OLE	$(-0.007995)\left(\frac{T90 - 312.121596}{23.264684}\right)\left(\frac{OLEF - 7.359624}{5.383804}\right)$	}

where

SULFUR, AROM, OLEF, OXYGEN, T50, and T90 are the value limits for the candidate and reference specifications identified in the Table 7 worksheet.

2. Exhaust HC Emissions for Tech 4

The HC emissions for the candidate ($y_{\text{Tech 4-CAND}}$) and reference ($y_{\text{Tech 4-REF}}$) specifications for Tech 4 are calculated as follows:

HC emissions Tech 4 = $y_{\text{Tech 4}}$ =

Description	Equation	
	Exp	
intercept	{-1.142182	+
RVP	(-0.019335)	+
Sulfur	$(0.079373)\left(\frac{SULFUR - 154.120828}{136.790450}\right)$	+
Aromatic HC	$(0.002047)\left(\frac{AROM - 27.317137}{6.880833}\right)$	+
Olefin	$(-0.010716)\left(\frac{OLEF - 6.549450}{4.715345}\right)$	+
Oxygen	$(-0.019880)\left(\frac{OXY - 1.536017}{1.248887}\right)$	+
T50	$(0.052939)\left(\frac{T50 - 205.261051}{17.324472}\right)$	+
T90	$(0.037684)\left(\frac{T90 - 310.931422}{20.847425}\right)$	+
T50ARO	$(0.019031)\left(\frac{T50 - 205.261051}{17.324472}\right)\left(\frac{AROM - 27.317137}{6.880833}\right)$	+

$$
\begin{aligned}
&\text{T50T50} && (0.017086)\left(\frac{T50 - 205.261051}{17.324472}\right)\left(\frac{T50 - 205.261051}{17.324472}\right) && + \\
&\text{T50OXY} && (0.013724)\left(\frac{T50 - 205.261051}{17.324472}\right)\left(\frac{OXY - 1.536017}{1.248887}\right) && + \\
&\text{T90T90} && (0.013914)\left(\frac{T90 - 310.931422}{20.847425}\right)\left(\frac{T90 - 310.931422}{20.847425}\right) && + \\
&\text{AROARO} && (-0.010999)\left(\frac{AROM - 27.317137}{6.880833}\right)\left(\frac{AROM - 27.317137}{6.880833}\right) && + \\
&\text{AROOXY} && (0.007221)\left(\frac{AROM - 27.317137}{6.880833}\right)\left(\frac{OXY - 1.536017}{1.248887}\right) && \Big\}
\end{aligned}
$$

where

For calculating the reference fuel HC emissions, SULFUR, AROM, OLEF, OXY, T50, and T90 are equal to the corresponding values for the reference specifications in the Table 7 worksheet.

For calculating the candidate fuel HC emissions, SULFUR, OLEF, and OXY are equal to the corresponding values for the candidate specifications in the Table 7 worksheet. The values for AROM, T50, and T90 are determined as follows:

If the value for the candidate Aromatics specification in the Table 7 worksheet is greater than $AROM_{(LIN)}$ then $AROM_{(LIN)}$ is the value for AROM where $AROM_{(LIN)}$ is calculated as follows:

$$AROM_{(LIN)} = -45.3466 + (1.8086 \times OXY) + (0.3436 \times T50)$$

If the value for the candidate T50 specification in the Table 7 worksheet is less than or equal to $AROM_{(LIN)}$, the Aromatics specification in the Table 7 worksheet is the value for AROM.

If the value for the candidate T50 specification in the Table 7 worksheet is less than $T50_{(LIN)}$ then $T50_{(LIN)}$ is the value for T50 where $T50_{(LIN)}$ is calculated as follows:

$$T50_{(LIN)} = 225.3 - (1.4 \times AROM) - (5.6 \times OXY)$$

If the value for the candidate T50 specification in the Table 7 worksheet is greater than or equal to $T50_{(LIN)}$, the T50 specification in the Table 7 worksheet is the value for T50.

If the value for the candidate fuel T90 specification in the Table 7 worksheet is less than the 283 value, then the 283 value is the value for T90.

If the value for the candidate T90 specification in the Table 7 worksheet is greater than or equal to the 283 value, then the T90 specification in the Table 7 worksheet is the value for T90.

3. Exhaust HC Emissions for Tech 5

The HC emissions for the candidate ($y_{\text{Tech 5-CAND}}$) and reference ($y_{\text{Tech 5-REF}}$) specifications for Tech 5 are calculated as follows:

HC emissions Tech 5 = $y_{\text{Tech 5}}$ =

Description	Equation	
	Exp	
intercept	{-2.671187	+
RVP	(-0.012824)	+
Sulfur	$(0.242238)\left(\frac{\text{SULFUR} - 144.628901}{140.912204}\right)$	+
Aromatic HC	$(0.003039)\left(\frac{\text{AROM} - 26.875944}{6.600312}\right)$	+
Olefin	$(-0.010908)\left(\frac{\text{OLEF} - 6.251891}{4.431845}\right)$	+
Oxygen	$(-0.007528)\left(\frac{\text{OXY} - 1.551772}{1.262823}\right)$	+
T50	$(0.056796)\left(\frac{\text{T50} - 206.020870}{16.582090}\right)$	+
T90	$(0.010803)\left(\frac{\text{T90} - 310.570200}{22.967591}\right)$	+
T50ARO	$(0.016761)\left(\frac{\text{T50} - 206.020870}{16.582090}\right)\left(\frac{\text{AROM} - 26.875944}{6.600312}\right)$	+

$$
\begin{aligned}
&\text{T50T50} && (0.019563)\left(\frac{T50 - 206.020870}{16.582090}\right)\left(\frac{T50 - 206.020870}{16.582090}\right) && + \\
&\text{T50OXY} && (0.014082)\left(\frac{T50 - 206.020870}{16.582090}\right)\left(\frac{OXY - 1.551772}{1.262823}\right) && + \\
&\text{T90T90} && (0.015216)\left(\frac{T90 - 310.570200}{22.967591}\right)\left(\frac{T90 - 310.570200}{22.9675901}\right) && + \\
&\text{T90OXY} && (0.013372)\left(\frac{T90 - 310.570200}{22.967590}\right)\left(\frac{OXY - 1.551772}{1.262823}\right) && + \\
&\text{AROARO} && (-0.009740)\left(\frac{AROM - 26.875944}{6.600312}\right)\left(\frac{AROM - 26.875944}{6.600312}\right) && + \\
&\text{AROOXY} && (0.006902)\left(\frac{AROM - 26.875944}{6.600312}\right)\left(\frac{OXY - 1.551772}{1.262823}\right) && \Big\}
\end{aligned}
$$

where

For calculating the reference fuel HC emissions, SULFUR, AROM, OLEF, OXY, T50, and T90 are equal to the corresponding values for the reference specifications in the Table 7 worksheet.

For calculating the candidate fuel HC emissions, SULFUR, OLEF, and OXY are equal to the corresponding values for the candidate specifications in the Table 7 worksheet. The values for AROM, T50, and T90 are determined as follows:

If the value for the candidate Aromatics specification in the Table 7 worksheet is greater than $AROM_{(LIN)}$ then $AROM_{(LIN)}$ is the value for AROM where $AROM_{(LIN)}$ is calculated as follows:

$$AROM_{(LIN)} = -45.5269 + (1.8518 \times OXY) + (0.3425 \times T50)$$

If the value for the candidate Aromatics specification in the Table 7 worksheet is less than or equal to $AROM_{(LIN)}$, the Aromatics specification in the Table 7 worksheet is the value for AROM.

If the value for the candidate T50 specification in the Table 7 worksheet is less than $T50_{(LIN)}$, then $T50_{(LIN)}$ is the value for T50, where $T50_{(LIN)}$ is calculated as follows:

$$T50_{(LIN)} = 218.2 - (1.1 \times AROM) - (4.7 \times OXY)$$

If the value for the candidate T50 specification in the Table 7 worksheet is greater than or equal to $T50_{(LIN)}$, the T50 specification in the Table 7 worksheet is the value for T50.

If the value for the candidate fuel T90 specification in the Table 7 worksheet is less than the $T90_{(LIN)}$ value, then the $T90_{(LIN)}$ value is the value for T90 where $T90_{(LIN)}$ is calculated as follows:

$$T90_{(LIN)} = 314.8 - (8.0 \times OXY)$$

If the value for the candidate T90 specification in the Table 7 worksheet is greater than or equal to the $T90_{(LIN)}$ value, then the T90 specification in the Table 7 worksheet is the value for T90.

B. Percent Change in Exhaust HC Emissions

The percent change in exhaust HC emissions between the candidate fuel specifications and the reference fuel specifications is calculated as follows:

$$\%CE_{EXHC} = \{\{[(y_{Tech\ 3\text{-}CAND} / y_{Tech\ 3\text{-}REF}) \times EWF_{3\text{-}HC}] + [(y_{Tech\ 4\text{-}CAND} / y_{Tech\ 4\text{-}REF}) \times EWF_{4\text{-}HC}] + [(y_{Tech\ 5\text{-}CAND} / y_{Tech\ 5\text{-}REF}) \times EWF_{5\text{-}HC}]\} - 1\} \times 100$$

where

$y_{Tech\ 3\text{-}CAND}$, $y_{Tech\ 4\text{-}CAND}$, and $y_{Tech\ 5\text{-}CAND}$ are the exhaust HC emissions for the candidate specifications in grams per mile for Tech 3, Tech 4, and Tech 5 respectively.

$y_{Tech\ 3\text{-}REF}$, $y_{Tech\ 4\text{-}REF}$, and $y_{Tech\ 5\text{-}REF}$ are the exhaust HC emissions for the reference specifications in grams per mile for Tech 3, Tech 4, and Tech 5 respectively.

The exhaust HC emissions for Tech 3 are calculated according to the equations in section V. A. 1.

The exhaust HC emissions for Tech 4 are calculated according to the equations in section V. A. 2.

The exhaust HC emissions for Tech 5 are calculated according to the equations in section V. A. 3.

$EWF_{3\text{-}HC}$, $EWF_{4\text{-}HC}$, and $EWF_{5\text{-}HC}$ are the emission-weighting factors for HC as shown in Table 4.

VI. CARBON MONOXIDE (CO) EMISSIONS CALCULATIONS

A. CO Emissions by Technology Class

The property values from the Table 6 worksheet are used to calculate CO emissions for the candidate and reference specifications.

1. CO Emissions for Tech 3

The CO emissions for the candidate ($y_{\text{Tech 3-CAND}}$) and reference ($y_{\text{Tech 3-REF}}$) specifications for Tech 3 are calculated as follows:

CO emissions Tech 3 = $y_{\text{Tech 3}}$ =

Description	Equation	
	Exp	
intercept	{1.615613	+
RVP	(0.012087)	+
Sulfur	$(0.031849)\left(\frac{\text{SULFUR} - 139.691080}{126.741459}\right)$	+
Aromatic HC	$(0.085541)\left(\frac{\text{AROM} - 30.212969}{8.682044}\right)$	+
Olefin	$(0.002416)\left(\frac{\text{OLEF} - 7.359624}{5.383804}\right)$	+
Oxygen	$(-0.068986)\left(\frac{\text{OXY} - 0.892363}{1.235405}\right)$	+
T50	$(0.009897)\left(\frac{\text{T50} - 212.245188}{15.880385}\right)$	+
T90	$(-0.025449)\left(\frac{\text{T90} - 312.121596}{23.264684}\right)$	+
T50T90	$(0.017463)\left(\frac{\text{T50} - 212.245188}{15.880385}\right)\left(\frac{\text{T90} - 312.121596}{23.264684}\right)$	}

where

SULFUR, AROM, OLEF, OXYGEN, T50, and T90 are the value limits for the candidate and reference specifications identified in the Table 7 worksheet.

2. CO Emissions for Tech 4

The CO emissions for the candidate ($y_{\text{Tech 4-CAND}}$) and reference ($y_{\text{Tech 4-REF}}$) specifications for Tech 4 are calculated as follows:

CO emissions Tech 4 = $y_{\text{Tech 4}}$ =

Description	Equation	
	Exp	
intercept	{1.195246	+
RVP	(-0.025878)	+
Sulfur	$(0.073616)\left(\frac{\text{SULFUR} - 154.120828}{136.790450}\right)$	+
Aromatic HC	$(0.025960)\left(\frac{\text{AROM} - 27.317137}{6.880833}\right)$	+
Olefin	$(0.001263)\left(\frac{\text{OLEF} - 6.549450}{4.715345}\right)$	+
Oxygen	$(-0.052530)\left(\frac{\text{OXY} - 1.536017}{1.248887}\right)$	+
T50	$(0.022750)\left(\frac{\text{T50} - 205.261051}{17.324472}\right)$	+
T90	$(-0.008820)\left(\frac{\text{T90} - 310.931422}{20.847425}\right)$	+
OXYOXY	$(-0.016510)\left(\frac{\text{OXY} - 1.536017}{1.248887}\right)\left(\frac{\text{OXY} - 1.536017}{1.248887}\right)$	+
T50ARO	$(0.009884)\left(\frac{\text{T50} - 205.261051}{17.324472}\right)\left(\frac{\text{AROM} - 27.317137}{6.880833}\right)$	+
T90OLE	$(-0.007360)\left(\frac{\text{T90} - 310.931422}{20.847425}\right)\left(\frac{\text{OLEF} - 6.549450}{4.715345}\right)$	+

T90T90	$(0.007767)\left(\frac{T90 - 310.931422}{20.847425}\right)\left(\frac{T90 - 310.931422}{20.847450}\right)$	}

where

For calculating the reference fuel CO emissions, SULFUR, AROM, OLEF, OXY, T50, and T90 are equal to the corresponding values for the reference specifications in the Table 7 worksheet.

For calculating the candidate fuel CO emissions, SULFUR, AROM, OLEF, OXY, and T50 are equal to the corresponding values for the candidate specifications in the Table 7 worksheet. The value for T90 is determined as follows:

If the value for the candidate fuel T90 specification in the Table 7 worksheet is greater than the $T90_{(LIN)}$ value, then the $T90_{(LIN)}$ value is the value for T90 where $T90_{(LIN)}$ is calculated as follows:

$$T90_{(LIN)} = 308.3 + (2.5 \times OLEF)$$

If the value for the candidate T90 specification in the Table 7 worksheet is less than or equal to the $T90_{(LIN)}$ value, then the T90 specification in the Table 7 worksheet is the value for T90.

3. CO Emissions for Tech 5

The CO emissions for the candidate ($y_{Tech\ 5\text{-}CAND}$) and reference ($y_{Tech\ 5\text{-}REF}$) specifications for Tech 5 are calculated as follows:

CO emissions Tech 5 = $y_{Tech\ 5}$ =

Description	Equation	
	Exp	
intercept	{-0.240521	+
RVP	(-0.014137)	+
Sulfur	$(0.123649)\left(\frac{SULFUR - 144.628901}{140.91224}\right)$	+

Aromatic HC $(0.025775)\left(\frac{AROM - 26.875944}{6.600312}\right)$ +

Olefin $(0.005001)\left(\frac{OLEF - 6.251891}{4.431845}\right)$ +

Oxygen $(-0.087967)\left(\frac{OXY - 1.551772}{1.262823}\right)$ +

T50 $(0.018195)\left(\frac{T50 - 206.020870}{16.582090}\right)$ +

T90 $(-0.128296)\left(\frac{T90 - 310.570200}{22.967591}\right)$ +

OXYOXY $(0.026309)\left(\frac{OXY - 1.551772}{1.262823}\right)\left(\frac{OXY - 1.551772}{1.262823}\right)$ +

T50ARO $(0.009797)\left(\frac{T50 - 206.020870}{16.582090}\right)\left(\frac{AROM - 26.875944}{6.600312}\right)$ +

T50OXY $(0.021763)\left(\frac{T50 - 206.020870}{16.582090}\right)\left(\frac{OXY - 1.551772}{1.262823}\right)$ }

where

For calculating the reference fuel CO emissions, SULFUR, AROM, OLEF, OXY, T50, and T90 are equal to the corresponding values for the reference specifications in the Table 7 worksheet.

For calculating the candidate fuel CO emissions, SULFUR, AROM, OLEF, T50, and T90 are equal to the corresponding values for the candidate specifications in the Table 7 worksheet. The value for OXY is determined as follows:

If the value for the candidate fuel Oxygen specification in the Table 7 worksheet is greater than the $OXY_{(LIN)}$ value, then the $OXY_{(LIN)}$ value is the value for OXY where $OXY_{(LIN)}$ is calculated as follows:

$$OXY_{(LIN)} = 10.152 - (0.0315 \times T50)$$

If the value for the candidate Oxygen specification in the Table 7 worksheet is less than or equal to the $OXY_{(LIN)}$ value, then the Oxygen specification in the Table 7 worksheet is the value for OXY.

B. Percent Change in CO Emissions

The percent change in CO emissions between the candidate fuel specifications and the reference fuel specifications is calculated as follows:

$$\%CE_{CO} = \{\{[(y_{Tech\ 3\text{-}CAND} / y_{Tech\ 3\text{-}REF}) \times EWF_{3\text{-}CO}] + [(y_{Tech\ 4\text{-}CAND} / y_{Tech\ 4\text{-}REF}) \times EWF_{4\text{-}CO}] + [(y_{Tech\ 5\text{-}CAND} / y_{Tech\ 5\text{-}REF}) \times EWF_{5\text{-}CO}]\} - 1\} \times 100$$

where

$y_{Tech\ 3\text{-}CAND}$, $y_{Tech\ 4\text{-}CAND}$, and $y_{Tech\ 5\text{-}CAND}$ are the CO emissions for the candidate specifications in grams per mile for Tech 3, Tech 4, and Tech 5 respectively.

$y_{Tech\ 3\text{-}REF}$, $y_{Tech\ 4\text{-}REF}$, and $y_{Tech\ 5\text{-}REF}$ are the CO emissions for the reference specifications in grams per mile for Tech 3, Tech 4, and Tech 5 respectively.

The CO emissions for Tech 3 are calculated according to the equations in section VI. A. 1.

The CO emissions for Tech 4 are calculated according to the equations in section VI. A. 2.

The CO emissions for Tech 5 are calculated according to the equations in section VI. A. 3.

$EWF_{3\text{-}CO}$, $EWF_{4\text{-}CO}$, and $EWF_{5\text{-}CO}$ are the emission-weighting factors for CO as shown in Table 4.

VII. POTENCY-WEIGHTED TOXICS (PWT) EXHAUST EMISSIONS CALCULATIONS

A. Mass Emissions of Toxics by Technology Class

The property values from the Table 7 worksheet are used to calculate mass toxic emissions for the candidate and reference specifications.

1. Mass Emissions for Tech 3

The mass emissions for each toxic for Tech 3 are calculated as follows:

a. Benzene mass emissions Tech 3 = $y_{\text{Tech 3}}$ =

Description	Equation	
	Exp	
intercept	{2.95676525	+
Sulfur	(0.0683768) $\frac{(\text{SULFUR} - 139.691080)}{126.741459}$	+
Aromatic HC	(0.15191575) $\frac{(\text{AROM} - 30.212969)}{8.682044}$	+
Oxygen	(-0.03295985) $\frac{(\text{OXY} - 0.892363)}{1.235405}$	+
BENZ	(-0.12025037) $\frac{(\text{BENZ} - 1.36412)}{0.513051}$	}

b. 1,3-Butadiene mass emissions Tech 3 = $y_{Tech\ 3}$ =

Description	Equation	
	Exp	
intercept	{0.67173886	+
Olefin	(0.18408319) $\frac{(OLEF - 7.359624)}{5.383804}$	+
T50	(0.11391774) $\frac{(T50 - 212.245188)}{15.880385}$	}

c. Formaldehyde mass emissions Tech 3 = $y_{\text{Tech 3}}$ =

Description	Equation	
	Exp	
intercept	{2.16836424	+
Aromatic HC	(-0.07537099) $\frac{(\text{AROM} - 30.212969)}{8.682044}$	+
Oxygen	(0.12278577) $\frac{(\text{OXY} - 0.892363)}{1.235405}$	+
Oxygen (as EtOH)[1]	(-0.12295089) (Type) $\frac{(\text{OXY} - 0.892363)}{1.235405}$	+
BENZ	(-0.1423482) $\frac{(\text{BENZ} - 1.36412)}{0.513051}$	}

1 — The Oxygen (as EtOH) term is an indicator variable term which is included only in the model prediction for the candidate fuel specifications, and only if the oxygen originates from the use of ethanol. This term is not included in the calculation for the reference fuel specifications because it is assumed that the oxygen from the reference fuel originates from the use of MTBE. Mathematically, this means that the value of Type in the above equation is 1.0 for the prediction for the candidate fuel specifications if ethanol is used, 0 for the prediction for the candidate fuel specifications if ethanol is not used, and 0 for all predictions for reference fuel specifications.

d. Acetaldehyde mass emissions Tech 3 = $y_{\text{Tech 3}}$ =

Description	Equation	
	Exp	
intercept	{1.10122139	+
Aromatic HC	(-0.09219416) $\frac{(\text{AROM} - 30.212969)}{8.682044}$	+
Oxygen	(0.00122983) $\frac{(\text{OXY} - 0.892363)}{1.235405}$	+
Oxygen (as EtOH)[1]	(0.54678495) (Type) $\frac{(\text{OXY} - 0.892363)}{1.235405}$	}

where

SULFUR, AROM, OLEF, OXYGEN, T50, and T90 are the value limits for the candidate and reference specifications identified in the Table 7 worksheet.

1 — The Oxygen (as EtOH) term is an indicator variable term which is included only in the model prediction for the candidate fuel specifications, and only if the oxygen originates from the use of ethanol. This term is not included in the calculation for the reference fuel specifications because it is assumed that the oxygen from the reference fuel originates from the use of MTBE. Mathematically, this means that the value of Type in the above equation is 1.0 for the prediction for the candidate fuel specifications if ethanol is used, 0 for the prediction for the candidate fuel specifications if ethanol is not used, and 0 for all predictions for reference fuel specifications.

2. Mass Emissions for Tech 4

The mass emissions for each toxic for Tech 4 are calculated as follows:

a. Benzene mass emissions Tech 4 = $y_{\text{Tech 4}}$ =

Description	Equation
	Exp
intercept	{2.3824773 +
	Exp
intercept	{2.3824773 +
RVP	(0.07392876) +
Sulfur	(0.09652526) $\left(\frac{\text{SULFUR} - 154.120828}{136.790450}\right)$ +
Aromatic HC	(0.15517085) $\left(\frac{\text{AROM} - 27.317137}{6.880833}\right)$ +
Olefin	(-0.02548759) $\left(\frac{\text{OLEF} - 6.549450}{4.715345}\right)$ +
T50	(0.04666208) $\left(\frac{\text{T50} - 205.261051}{17.324472}\right)$ +
BENZ	(0.11689441) $\left(\frac{\text{BENZ} - 1.014259}{0.537392}\right)$ }

b. 1,3-Butadiene mass emissions Tech 4 = $y_{Tech\ 4}$ =

Description	Equation	
	Exp	
intercept	{0.43090426	+
Aromatic HC	(-0.03604344) $\frac{(AROM - 27.317137)}{6.880833}$	+
Olefin	(0.10354089) $\frac{(OLEF - 6.549450)}{4.715345}$	+
Oxygen	(-0.02511374) $\frac{(OXY - 1.536017)}{1.248887}$	+
T50	(0.03707822) $\frac{(T50 - 205.261051)}{17.324472}$	+
T90	(0.09454201) $\frac{(T90 - 310.931422)}{20.847425}$	+
BENZ	(0.03644387) $\frac{(BENZ - 1.01425)}{0.537392}$	}

c. Formaldehyde mass emissions Tech 4 = $y_{\text{Tech 4}}$ =

Description	Equation	
	Exp	
intercept	{1.05886661	+
Sulfur	(-0.04135075) $\frac{(\text{SULFUR} - 154.120828)}{136.790450}$	+
Aromatic HC	(-0.05466283) $\frac{(\text{AROM} - 27.317137)}{6.880833}$	+
Oxygen	(0.06370091) $\frac{(\text{OXY} - 1.536017)}{1.248887}$	+
Oxygen (as EtOH)[1]	(-0.09819814) (Type) $\frac{(\text{OXY} - 1.536017)}{1.248887}$	+
T90	(0.06037698) $\frac{(\text{T90} - 310.981422)}{20.847425}$	}

1 — The Oxygen (as EtOH) term is an indicator variable term which is included only in the model prediction for the candidate fuel specifications, and only if the oxygen originates from the use of ethanol. This term is not included in the calculation for the reference fuel specifications because it is assumed that the oxygen from the reference fuel originates from the use of MTBE. Mathematically, this means that the value of Type in the above equation is 1.0 for the prediction for the candidate fuel specifications if ethanol is used, 0 for the prediction for the candidate fuel specifications if ethanol is not used, and 0 for all predictions for reference fuel specifications.

d. Acetaldehyde mass emissions Tech 4 = $y_{\text{Tech 4}}$ =

Description	Equation	
	Exp	
intercept	{0.16738341	+
Sulfur	(0.02788263) $\frac{(\text{SULFUR} - 154.120828)}{136.790450}$	+
Aromatic HC	(-0.05552641) $\frac{(\text{AROM} - 27.317137)}{6.880833}$	+
Oxygen	(0.02382123) $\frac{(\text{OXY} - 1.536017)}{1.248887}$	+
Oxygen (as EtOH)[1]	(0.46699012) (Type) $\frac{(\text{OXY} - 1.536017)}{1.248887}$	+
T50	(0.04314573) $\frac{(\text{T50} - 205.261051)}{17.324472}$	+
T90	(0.06252964) $\frac{(\text{T90} - 310.931422)}{20.847425}$	+
BENZ	(0.06148653) $\frac{(\text{BENZ} - 1.014259)}{0.537392}$	}

where

SULFUR, AROM, OLEF, OXYGEN, T50, and T90 are the values for the candidate and reference specifications in the Table 7 worksheet.

1 — The Oxygen (as EtOH) term is an indicator variable term which is included only in the model prediction for the candidate fuel specifications, and only if the oxygen originates from the use of ethanol. This term is not included in the calculation for the reference fuel specifications because it is assumed that the oxygen from the reference fuel originates from the use of MTBE. Mathematically, this means that the value of Type in the above equation is 1.0 for the prediction for the candidate fuel specifications if ethanol is used, 0 for the prediction for the candidate fuel specifications if ethanol is not used, and 0 for all predictions for reference fuel specifications.

3. Mass Emissions for Tech 5

The mass emissions for each toxic for Tech 5 are calculated as follows:

a. Benzene mass emissions Tech 5 = $y_{\text{Tech 5}}$ =

Description	Equation	
	Exp	
intercept	{2.3824773	+
RVP	(0.06514198)	+
Sulfur	(0.09652526) $\frac{(\text{SULFUR} - 144.628901)}{140.91224}$	+
Aromatic HC	(0.15517085) $\frac{(\text{AROM} - 26.875944)}{6.600312}$	+
Olefin	(-0.02548759) $\frac{(\text{OLEF} - 6.251891)}{4.431845}$	+
T50	(0.04666208) $\frac{(\text{T50} - 206.020870)}{16.582090}$	+
BENZ	(0.11689441) $\frac{(\text{BENZ} - 0.969248)}{0.504325}$	}

b. 1,3-Butadiene mass emissions Tech 5 = $y_{Tech\ 5}$ =

Description	Equation	
	Exp	
intercept	{0.43090426	+
Aromatic HC	(-0.03604344) (AROM - 26.875944) / 6.600312	+
Olefin	(0.10354089) (OLEF - 6.251891) / 4.431845	+
Oxygen	(-0.02511374) (OXY - 1.551772) / 1.262823	+
T50	(0.03707822) (T50 - 206.020870) / 16.582090	+
T90	(0.09454201) (T90 - 310.570200) / 22.967591	+
BENZ	(0.03644387) (BENZ - 0.969248) / 0.504325	}

c. Formaldehyde mass emissions Tech 5 = $y_{\text{Tech 5}}$ =

Description	Equation	
	Exp	
intercept	{1.05886661	+
Sulfur	(-0.04135075) $\frac{(\text{SULFUR} - 144.628901)}{140.91224}$	+
Aromatic HC	(-0.05466283) $\frac{(\text{AROM} - 26.875940)}{6.600312}$	+
Oxygen	(0.06370091) $\frac{(\text{OXY} - 1.551772)}{1.262823}$	+
Oxygen (as EtOH)[1]	(-0.09819814) (Type) $\frac{(\text{OXY} - 1.551772)}{1.262823}$	+
T90	(0.000000) $\frac{(\text{T90} - 310.570200)}{22.967591}$	}

1 — The Oxygen (as EtOH) term is an indicator variable term which is included only in the model prediction for the candidate fuel specifications, and only if the oxygen originates from the use of ethanol. This term is not included in the calculation for the reference fuel specifications because it is assumed that the oxygen from the reference fuel originates from the use of MTBE. Mathematically, this means that the value of Type in the above equation is 1.0 for the prediction for the candidate fuel specifications if ethanol is used, 0 for the prediction for the candidate fuel specifications if ethanol is not used, and 0 for all predictions for reference fuel specifications.

d. Acetaldehyde mass emissions Tech 5 = $y_{\text{Tech 5}}$ =

Description	Equation	
	Exp	
intercept	{0.16738341	+
Sulfur	(0.02788263) $\frac{(\text{SULFUR} - 144.628901)}{140.91224}$	+
Aromatic HC	(-0.05552641) $\frac{(\text{AROM} - 26.875944)}{6.600312}$	+
Oxygen	(0.02382123) $\frac{(\text{OXY} - 1.551772)}{1.262823}$	+
Oxygen (as EtOH)[1]	(0.046699012) (Type) $\frac{(\text{OXY} - 1.551772)}{1.262823}$	+
T50	(0.04314573) $\frac{(\text{T50} - 206.020870)}{16.582090}$	+
T90	(0.06252964) $\frac{(\text{T90} - 310.570200)}{22.967591}$	+
BENZ	(0.06148653) $\frac{(\text{BENZ} - 0.969248)}{0.504325}$	}

where

SULFUR, AROM, OLEF, OXYGEN, T50, and T90 are the values for the candidate and reference specifications in the Table 7 worksheet.

1 — The Oxygen (as EtOH) term is an indicator variable term which is included only in the model prediction for the candidate fuel specifications, and only if the oxygen originates from the use of ethanol. This term is not included in the calculation for the reference fuel specifications because it is assumed that the oxygen from the reference fuel originates from the use of MTBE. Mathematically, this means that the value of Type in the above equation is 1.0 for the prediction for the candidate fuel specifications if ethanol is used, 0 for the prediction for the candidate fuel specifications if ethanol is not used, and 0 for all predictions for reference fuel specifications.

B. Computation of Total Potency-Weighted Exhaust Toxics Emissions

1. Calculation of Potency-weighted Exhaust Toxics Emissions for Candidate Specifications

$$EX_{PWT\text{-}CAND} =$$

$$\{((y_{BZ\text{-}TECH3} \times TWF_3)+(y_{BZ\text{-}TECH4} \times TWF_4)+(y_{BZ\text{-}TECH5} \times TWF_5))x(PWF_{BZ})\} +$$

$$\{((y_{BD\text{-}TECH3} \times TWF_3)+(y_{BD\text{-}TECH4} \times TWF_4)+(y_{BD\text{-}TECH5} \times TWF_5))x(PWF_{BD})\} +$$

$$\{((y_{FOR\text{-}TECH3} \times TWF_3)+(y_{FOR\text{-}TECH4} \times TWF_4)+(y_{FOR\text{-}TECH5} \times TWF_5))x(PWF_{FOR})\} +$$

$$\{((y_{ACE\text{-}TECH3} \times TWF_3)+(y_{ACE\text{-}TECH4} \times TWF_4)+(y_{ACE\text{-}TECH5} \times TWF_5))x(PWF_{ACE})\}$$

where

$EX_{PWT\text{-}CAND}$ is the PWT emissions for the candidate specifications.

$y_{BZ\text{-}TECH}$ is the benzene emissions prediction for Tech 3, Tech 4, or Tech 5,
$y_{BD\text{-}TECH}$ is the 1,3-butadiene emissions prediction for Tech 3, Tech 4, or Tech 5,
$y_{FOR\text{-}TECH}$ is the formaldehyde emissions prediction for Tech 3, Tech 4, or Tech 5,
$y_{ACE\text{-}TECH}$ is the acetaldehyde emissions prediction for Tech 3, Tech 4, or Tech 5.

TWF_3, TWF_4, and TWF_5 are the toxics weighting factors for Tech class 3, Tech class 4, and Tech class 5 vehicles, respectively. These values are shown in Table 5.

PWF_q is the potency weighting factor for toxic pollutant q provided in Table 8.

2. Calculation of Potency-Weighted Emissions for Reference Specifications

$$EX_{PWT\text{-}REF} =$$

$$\{((y_{BZ\text{-}TECH3} \times TWF_3)+(y_{BZ\text{-}TECH4} \times TWF_4)+(y_{BZ\text{-}TECH5} \times TWF_5))x(PWF_{BZ})\} +$$

$$\{((y_{BD\text{-}TECH3} \times TWF_3)+(y_{BD\text{-}TECH4} \times TWF_4)+(y_{BD\text{-}TECH5} \times TWF_5))x(PWF_{BD})\} +$$

$$\{((y_{FOR\text{-}TECH3} \times TWF_3)+(y_{FOR\text{-}TECH4} \times TWF_4)+(y_{FOR\text{-}TECH5} \times TWF_5))x(PWF_{FOR})\} +$$

$$\{((y_{ACE\text{-}TECH3} \times TWF_3)+(y_{ACE\text{-}TECH4} \times TWF_4)+(y_{ACE\text{-}TECH5} \times TWF_5))x(PWF_{ACE})\}$$

where

$EX_{PWT\text{-}REF}$ is the PWT emissions for the reference specifications.

$y_{BZ\text{-}TECH}$ is the benzene emissions prediction for Tech 3, Tech 4, or Tech 5,
$y_{BD\text{-}TECH}$ is the 1,3-butadiene emissions prediction for Tech 3, Tech 4, or Tech 5,
$y_{FOR\text{-}TECH}$ is the formaldehyde emissions prediction for Tech 3, Tech 4, or Tech 5,
$y_{ACE\text{-}TECH}$ is the acetaldehyde emissions prediction for Tech 3, Tech 4, or Tech 5.

TWF_3, TWF_4, and TWF_5 are the toxics_weighting factors for Tech class 3, Tech class 4, and Tech class 5 vehicles, respectively. These values are shown in Table 5.

PWF_q is the potency-weighting factor for toxic pollutant q provided in Table 8.

VIII. CALCULATIONS FOR CHANGES IN EVAPORATIVE HYDROCARBON (HC) EMISSIONS

A. Evaporative HC Emissions by Process

The evaporative HC models predict the percent change in evaporative HC emissions as a function of RVP in psi, relative to a reference fuel's RVP. As stated in Table 1, the RVP of the reference fuel is 7.0 psi for an ethanol blended candidate fuel or 6.9 psi for a non-oxygenated candidate fuel. Thus, the models predict the percent change in evaporative HC emissions of the candidate fuel relative to a particular reference fuel. There are three evaporative HC models for each type of candidate fuel, i.e., oxygenated (ethanol) and non-oxygenated candidate fuels. The three HC models are for each of the following three evaporative emissions processes: 1) Diurnal/Resting Loss Emissions, 2) Hot Soak Emissions, and 3) Running Loss Emissions.

1. Diurnal/Resting Loss Emissions

a. The predicted percent change in Diurnal/Resting Loss Emissions (% CE_{DIRES}) of an oxygenated candidate fuel is:

$$\% \, CE_{DIRES} = \frac{100 \times [43.589427 + (3.730921 \times RVP)]}{[34.535116 + (3.730921 \times 7.0)]} - 100$$

where RVP is the RVP of the candidate fuel.

b. The predicted percent change in Diurnal/Resting Loss Emissions (% CE_{DIRES}) of a non-oxygenated candidate fuel is:

$$\% \, CE_{DIRES} = \frac{100 \times [34.535116 + (3.730921 \times RVP)]}{[34.535116 + (3.730921 \times 6.9)]} - 100$$

where RVP is the RVP of the candidate fuel.

2. Hot Soak Emissions

a. The predicted percent change in Hot Soak Emissions (% CE_{HS}) of an oxygenated candidate fuel is:

$$\% \, CE_{HS} = \frac{100 \times [10.356585 + (4.369978 \times RVP)]}{[9.228675 + (4.369978 \times 7.0)]} - 100$$

where RVP is the RVP of the candidate fuel.

b. The predicted percent change in Hot Soak Emissions (% CE_{HS}) of a non-oxygenated candidate fuel is:

$$\% \mathbf{CE}_{HS} = \frac{100 \times [9.228675 + (4.369978 \times RVP)]}{[9.228675 + (4.369978 \times 6.9)]} - 100$$

where RVP is the RVP of the candidate fuel.

3. Running Loss Emissions

a. The predicted percent change in Running Loss (% $\mathbf{CE}_{RL}$) of an oxygenated candidate fuel is:

$$\% \mathbf{CE}_{RL} = \frac{100 \times [42.517912 + (9.744935 \times RVP)]}{[40.567912 + (9.744935 \times 7.0)]} - 100$$

where RVP is the RVP of the candidate fuel.

b. The predicted percent change in Running Loss (% $\mathbf{CE}_{RL}$) of a non-oxygenated candidate fuel is:

$$\% \mathbf{CE}_{RL} = \frac{100 \times [40.567912 + (9.744935 \times RVP)]}{[40.567912 + (9.744935 \times 6.9)]} - 100$$

where RVP is the RVP of the candidate fuel.

IX. EVAPORATIVE BENZENE EMISSIONS CALCULATIONS

A. Evaporative Benzene Emissions by Process

The evaporative benzene models predict the evaporative benzene emissions (in units of milligrams per mile) as a function of RVP, gasoline benzene content, and gasoline MTBE content (for Hot Soak Benzene Emissions). There are three evaporative benzene models, one for each of the following three processes of evaporative benzene emissions: 1) Diurnal/Resting Loss Emissions, 2) Hot Soak Emissions, and 3) Running Loss Emissions.

1. Diurnal/Resting Loss Emissions

The predicted Diurnal/Resting Loss Benzene Emissions ($EVBenz_{DIRES}$) of an ethanol containing fuel is calculated as follows:

$$EVBenz_{DIRES} = \{592 \times [(3.730921 \times RVP + 43.589427) \times 907.18 / 939430)] \times [(0.0294917804 \times Benz) - (0.0017567009 \times Benz \times RVP)]\}$$

The predicted Diurnal/Resting Loss Benzene Emissions ($EVBenz_{DIRES}$) of a non-ethanol containing fuel is calculated as follows:

$$EVBenz_{DIRES} = \{592 \times [(3.730921 \times RVP + 34.535116) \times 907.18 / 939430)] \times [(0.0294917804 \times Benz) - (0.0017567009 \times Benz \times RVP)]\}$$

where

$EVBenz_{DIRES}$ is the predicted evaporative Diurnal/Resting Loss benzene emissions and is calculated for both the reference and candidate fuel specifications,
Benz is the benzene content of the gasoline, in percent by volume, and
RVP is the RVP of the gasoline, in psi.

2. Hot Soak Loss Emissions

The predicted Hot Soak Benzene emissions ($EVBenz_{HS}$) is calculated as follows:

$$EVBenz_{HS} = \{592 \times [(4.369978 \times RVP + 10.356585) \times 907.18 / 939430] \times [(0.0463141591 \times Benz) - (0.0027179513 \times Benz \times RVP) - (0.0008184128 \times Benz \times MTBE)]\}$$

The predicted Hot Soak Benzene emissions ($EVBenz_{HS}$) of a non-ethanol containing gasoline is calculated as follows:

$$EVBenz_{HS} = \{592 \times [(4.369978 \times RVP + 9.228675) \times 907.18 / 939430] \times [(0.0463141591 \times Benz) - (0.0027179513 \times Benz \times RVP) - (0.0008184128 \times Benz \times MTBE)]\}$$

where

$EVBenz_{HS}$	is the predicted evaporative Hot Soak benzene emissions and is calculated for both the reference and candidate fuel specifications,
Benz	is the benzene content of the gasoline, in percent by volume,
RVP	is the RVP of the gasoline, in psi, and
MTBE	is the MTBE content of the gasoline, in percent by volume.

3. Running Loss Emissions

The predicted Running Loss Benzene emissions ($EVBenz_{RL}$) of an ethanol containing gasoline is calculated as follows:

$$EVBenz_{RL} = \{592 \times [(9.744935 \times RVP + 42.517912) \times 907.18 / 939430] \times [(0.0648391842 \times Benz) - (0.005622979 \times Benz \times RVP)]\}$$

The predicted Running Loss Benzene emissions ($EVBenz_{RL}$) of a non-ethanol containing gasoline is calculated as follows:

$$EVBenz_{RL} = \{592 \times [(9.744935 \times RVP + 40.567912) \times 907.18 / 939430] \times [(0.0648391842 \times Benz) - (0.005622979 \times Benz \times RVP)]\}$$

where

$EVBenz_{RL}$ is the predicted evaporative Running Loss benzene emissions and is calculated for both the reference and candidate fuel specifications,

Benz is the benzene content of the gasoline, in percent by volume, and

RVP is the RVP of the gasoline, in psi.

X. COMBINATION OF EXHAUST HC EMISSIONS PREDICTIONS, EVAPORATIVE HC EMISSIONS PREDICTIONS, AND CO EMISSIONS PREDICTIONS

In combining the model predictions for exhaust HC, evaporative HC, and CO emissions, the ozone-forming potential of each of the three processes is recognized. The predicted percent change in emissions for each process is multiplied by a factor which represents, for that process, the ozone-forming potential of the emissions. For purposes of this discussion, this ozone-forming potential value will be referred to as relative reactivity. The predicted percent change for each process is also multiplied by a factor which represents the relative contribution of the process to the total inventory of reactive ozone precursors (HC and CO) from gasoline vehicles. The products of the predicted changes in emissions, relative reactivities, and contribution factors are then added. This sum is then divided by the sum of the products of the individual reactivities and emissions contribution fractions for each process. This quotient represents the percent change in the ozone-forming potential of the candidate fuel specifications relative to the reference fuel specifications.

The predicted percent change in exhaust HC emissions is the Tech class-weighted predicted change computed in accordance with the equation shown in Section V.B. For evaporative HC emissions, each of the individual evaporative processes (Diurnal/Resting, Hot Soak, and Running) has a different relative reactivity. Thus, for the evaporative emissions processes, the products of the predicted change in emissions and relative reactivity are computed separately. These three products are included individually in the overall sum. The predicted percent change in the three evaporative HC emissions processes are those computed in accordance with the equations given in Sections VIII.A.1, VIII.A.2, and VIII.A.3. The predicted percent change in CO emissions is the prediction computed in accordance with the equation given in section VI.B.

The combination of the exhaust HC, the evaporative HC, and the CO model predictions can be illustrated mathematically as follows: (Note that this calculation is performed only if the applicant selects the compliance option which provides for the use of the evaporative HC emissions models and the CO adjustment factor.)

$$\%CE_{OFP} = [(\%CE_{EXHC} \times R_{EXHC} \times F_{EXHC}) + (\%CE_{DIRES} \times R_{DIRES} \times F_{DIRES}) + (\%CE_{HS} \times R_{HS} \times F_{HS}) + (\%CE_{RL} \times R_{RL} \times F_{RL}) + (\%CE_{CO} \times R_{CO} \times F_{CO})] \; / \; [(R_{EXHC} \times F_{EXHC}) + (R_{DIRES} \times F_{DIRES}) + (R_{HS} \times F_{HS}) + (R_{RL} \times F_{RL}) + (R_{CO} \times F_{CO})]$$

where

$\%CE_{OFP}$ is the net percent change in ozone-forming potential of the reference fuel specifications relative to the candidate fuel specifications,

$\%CE_{EXHC}$ is the predicted percent change in Tech-class weighted exhaust HC as given by the equation in Section V.B,

$\%CE_{DIRES}$ is the predicted percent change in Diurnal/Resting Loss emissions as given by

the equation in Section VIII.A.1,
$\%CE_{HS}$ is the predicted percent change in Hot Soak emissions as given by the equation in Section VIII.A.2,
$\%CE_{RL}$ is the predicted percent change in Running Loss emissions as given by the equation in Section VII.A.3,
$\%CE_{CO}$ is the predicted percent change in CO emissions as given by the equation in Section VI.B, and

the R's are the relative reactivities as shown below in Table 9, and the F's are the fractions of emissions from gasoline vehicles for each process in the year 2015, as given by the ARB's EMFAC2007 motor vehicle emissions model and shown below in Table 10.

Table 9
Relative Reactivity Values

Process	R Value
Exhaust HC	1.00
Diurnal/Resting HC	0.68
Hot Soak HC	0.78
Running Loss HC	0.68
CO	0.015

Table 10
Emissions Fractions

Process	F Value
Exhaust HC	0.0454
Diurnal/Resting HC	0.0174
Hot Soak HC	0.0113
Running Loss HC	0.0310
CO	0.8949

XI. COMBINATION OF EXHAUST TOXICS EMISSIONS PREDICTIONS WITH EVAPORATIVE BENZENE EMISSIONS PREDICTIONS

The Diurnal/Resting Loss, Hot Soak, and Running Loss evaporative benzene predictions are each multiplied by the toxic air contaminant potency-weighting factor for benzene given in Table 8, and then summed to give the total potency-weighted evaporative benzene prediction. This prediction is then added to the total Tech class-weighted, potency-weighted exhaust toxics predictions computed in accordance with the equations given in Section V.B to give the total Tech class-weighted, potency-weighted toxics emissions predictions. The addition is performed for both the candidate fuel and the reference fuel. The combination is shown mathematically below:

A. Total Toxics for the Candidate Fuel Specifications:

Total Potency-Weighted Evaporative Benzene Prediction

$$EVBENZ_{TOT\text{-}CAND} = (EVBENZ_{DIRES\text{-}CAND} + EVBENZ_{HS\text{-}CAND} + EVBENZ_{RL\text{-}CAND}) \times PWF_{BENZ}$$

Total Potency-Weighted Toxics Prediction

$$E_{PWT\text{-}CAND} = EX_{PWT\text{-}CAND} + EVBENZ_{TOT\text{-}CAND}$$

where

$EVBENZ_{TOT\text{-}CAND}$ is the total potency-weighted evaporative benzene emission prediction for the candidate fuel specifications,

$EVBENZ_{DIRES\text{-}CAND}$ is the diurnal/resting loss benzene emission prediction for the candidate fuel specifications, as given by the equation in Section IX.A.1,

$EVBENZ_{HS\text{-}CAND}$ is the hot soak benzene emission prediction for the candidate fuel specifications, as given by the equation in Section IX.A.2,

$EVBENZ_{RL\text{-}CAND}$ is the running loss benzene emission prediction for the candidate fuel specifications, as given by the equation in Section IX.A.3,

PWF_{BENZ} is the potency-weighting factor for benzene shown in Table 8,

$E_{PWT\text{-}CAND}$ is the total potency-weighted toxics prediction for the candidate fuel specifications, and

$EX_{PWT\text{-}CAND}$ is the total Tech class-weighted, potency-weighted exhaust toxics prediction for the candidate fuel specifications computed in accordance with the equation give in Section VII.B.1.

B. Total Toxics for the Reference Fuel Specifications

Total Potency-Weighted Evaporative Benzene Prediction

$$EVBENZ_{TOT\text{-}REF} = (EVBENZ_{DIRES\text{-}REF} + EVBENZ_{HS\text{-}REF} + EVBENZ_{RL\text{-}REF}) \times PWF_{BENZ}$$

Total Potency-Weighted Toxics Prediction

$$E_{PWT\text{-}REF} = EX_{PWT\text{-}REF} + EVBENZ_{TOT\text{-}REF}$$

where

$EVBENZ_{TOT\text{-}REF}$ is the total potency-weighted evaporative benzene emission prediction for the reference fuel specifications,

$EVBENZ_{DIRES\text{-}REF}$ is the diurnal/resting loss benzene emission prediction for the reference fuel specifications, as given by the equation in Section IX.A.1,

$EVBENZ_{HS\text{-}REF}$ is the hot soak benzene emission prediction for the reference fuel specifications, as given by the equation in Section IX.A.2,

$EVBENZ_{RL\text{-}REF}$ is the running loss benzene emission prediction for the reference fuel specifications, as given by the equation in Section IX.A.3,

PWF_{BENZ} is the potency-weighting factor for benzene shown in Table 8

$E_{PWT\text{-}REF}$ is the total potency-weighted toxics prediction for the reference fuel specifications, and

$EX_{PWT\text{-}REF}$ is the total Tech class-weighted, potency-weighted exhaust toxics prediction for the reference fuel specifications computed in accordance with the equation give in Section VII.B.2.

C. Calculation of the Percent Change in Total Predicted Toxics Emissions

The percent change in the total predicted toxics emissions between the candidate fuel specifications and the reference fuel specification is calculated as follows:

$$\%CE_{PWT} = \left[(E_{PWT\text{-}CAND} - E_{PWT\text{-}REF}) / E_{PWT\text{-}REF}\right] \times 100$$

XII. DETERMINATION OF ACCEPTABILITY

If, for each pollutant (NOx, Ozone-forming Potential (OFP) or exhaust HC (EXHC), and Potency-Weighted Toxics (PWT)), the percent difference in emissions between the candidate fuel specifications and the reference Phase 3 RFG specifications is equal to or less than 0.04%, the candidate specifications are deemed acceptable as an alternative to Phase 3 RFG. If the applicant selects the compliance option which provides for the use of the evaporative HC emissions models, the candidate fuel specifications must pass for NOx, OFP, and PWT to be acceptable as an alternative Phase 3 RFG formulation. If the applicant does not select the compliance option which provides for the use of the evaporative HC emissions models, the candidate fuel specifications must pass for NOx, EXHC, and PWT to be acceptable as an alternative Phase 3 RFG formulation.

These criteria are mathematically shown below.

Applicant Elects to Use the Evaporative HC Emissions Model Compliance Option During *the RVP Control Season*

$$\%CE_{NOx} \leq 0.04\%, \text{ and}$$
$$\%CE_{OFP} \leq 0.04\%, \text{ and}$$
$$\%CE_{PWT} \leq 0.04\%.$$

Applicant Elects not to Use the Evaporative HC Emissions Model Compliance Option During the RVP Control Season, or Outside of the RVP Control Season

$$\%CE_{NOx} \leq 0.04\%, \text{ and}$$
$$\%CE_{EXHC} \leq 0.04\%, \text{ and}$$
$$\%CE_{PWT} \leq 0.04\%.$$

where

$\%CE_{NOx}$ is given by the equation in Section IV.B,
$\%CE_{OFP}$ is given by the equation in Section X,
$\%CE_{EXHC}$ is given by the equation in Section V.B, and
$\%CE_{PWT}$ is given by the equation in Section XI.C.

If the percent change in emission between the candidate specifications and the reference Phase 3 RFG specifications is equal to or greater than 0.05% for any pollutant (NOx, OFP, EXHC, PWT) in the above equivalency criteria, then the candidate specifications are deemed unacceptable and may not be a substitute for Phase 3 RFG. [Note: All final values of the percent change in emissions shall be reported to the nearest hundredth using conventional rounding.]

If the candidate specifications are deemed acceptable, the property values and the compliance options of the candidate specifications become the property values and compliance options for the alternative gasoline formulation.

XIII. NOTIFICATION OF INTENT TO OFFER AN ALTERNATIVE GASOLINE FORMULATION

A producer or importer intending to sell or supply an alternative gasoline formulation of California gasoline from its production facility or import facility shall notify the executive officer in accordance with 13 CCR, section 2265(a).

Table 11, Alternative Specifications for Phase 3 RFG Using the California Predictive Model Notification, has been provided as an example of the minimum information required.

Table 11
Alternative Specifications for Phase 3 RFG
Using California Predictive Model Notification

Name of Producer/Importer:_____Facility Location:
Name of Person Reporting:_____Telephone No:
Date/Time of This Report:_____ I.D. of 1st Batch with this Specification:
Notification Date: *Notification Time:*
Start Production Date: *Start Production Time:*
Batch Number: *Tank Number:*

- All California gasoline transferred from this facility will meet the specifications listed below until the next Alternative Specifications report to the ARB.
- Fuel properties that will be averaged will be reported as the "Designated Alternative Limit and Volume of Gasoline Report" separately to the ARB.

Compliance Option (check one): Evap. Option_____Exhaust-Only Option

Fuel Property	**Candidate Fuel Property Value**	**Compliance Option:**	**Reference Fuel: Phase 3 RFG Property Value**	
			Flat	**Average**
RVP		**Flat**	**6.90/7.00**	**None**
Sulfur			**20**	**15**
Benzene			**0.80**	**0.70**
Aromatic HC			**25.0**	**22.0**
Olefin			**6.0**	**4.0**
Oxygen[1]	**(min.)** / **(max.)**	**Flat Range**	**(min.)** / **(max.)**	**None**
T50			**213**	**203**
T90			**305**	**295**

1- See Table 6 in the Predictive Model Procedures for the specification of candidate and reference oxygen levels.

Pollutant[2]	**Percent Change in Emissions[3]**
Oxides of Nitrogen	
OFP or Exhaust HC	
Potency-Weighted Toxics	

2- Where Applicable, a %CE must be reported for both the candidate fuel minimum and maximum oxygen specifications. See Table 6 for explanation of when both %CE's must be reported.

3- Percent change calculated using equations presented in sections IV.B, V.B, VI.B, and X of the Phase 3 Predictive Model Procedures Document.

Table 12
Standardization of Fuel Properties - Mean and Standard Deviation

Fuel Property	Tech 3		Tech 4		Tech 5	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
RVP	8.670892	0.635066	8.365415	0.8891114	8.221700	0.902838
Sulfur	139.691080	126.741459	154.120828	136.790450	144.628901	140.912204
Aromatic HC	30.212969	8.682044	27.317137	6.880833	26.875944	6.600312
Olefin	7.359624	5.383804	6.549450	4.715345	6.251891	4.431845
Oxygen	0.892363	1.235405	1.536017	1.248887	1.551772	1.262623
T50	212.245188	15.880385	205.261051	17.324472	206.020870	16.582090
T90	312.121596	23.264684	310.931422	20.847425	310.570200	22.967591
Benzene	1.36412	0.513051	1.014259	0.537392	1.014259	0.537392

Table 13
Coefficients for NOx, Exhaust HC, and CO Equations

Model Term	Tech 3			Tech 4			Tech 5		
	NOx	HC	CO	NOx	HC	CO	NOx	HC	CO
Intercept	-0.159800	-0.752270	1.615613	-0.634694	-1.142182	1.195246	-1.599255	-2.671187	-0.240521
RVP	0.424915	0.000013	0.012087	-0.007046	-0.019335	-0.025878	-0.000533	-0.012824	-0.014137
Sulfur	0.028040	0.038207	0.031849	0.051043	0.079373	0.073616	0.947915	0.242238	0.123649
Aromatic HC	0.047060	0.014103	0.085541	0.011366	0.002047	0.025960	0.013671	0.003039	0.025775
Olefin	0.021110	-0.016533	0.002416	0.017193	-0.010716	0.001263	0.017335	-0.010908	0.005001
Oxygen	0.014910	-0.026365	-0.068986	0.028711	-0.019880	-0.052530	0.016036	-0.007528	-0.087967
T50	-0.007360	0.015847	0.009897	-0.002431	0.052939	0.022750	0.012397	0.056796	0.018195
T90	0.000654	0.011768	-0.025449	0.002087	0.037684	-0.008820	0.000762	0.010803	-0.128296
T90ARO		0.016606		-0.002892					
T90OLE		-0.007995				-0.007360			
T50T90			0.017463						
T50T50				0.006268	0.017086		-0.022211	0.019563	
OXYOXY				0.010737		-0.016510	0.015199		0.026309
T50ARO					0.019031	0.009884		0.016761	0.009797
T50OXY					0.013724		-0.015564	0.014082	0.021763
T90T90					0.013914	0.007767		0.015216	
AROARO					-0.010999			-0.009740	
AROOXY					0.007221			0.006902	

Model Term	Tech 3			Tech 4			Tech 5		
	NOx	HC	CO	NOx	HC	CO	NOx	HC	CO
T90OXY								0.013372	

Table 14
Coefficients for Exhaust Toxics Equations

Model Term	Tech 3			
	Benzene	Butadiene	Formaldehyde	Acetaldehyde
Intercept	2.95676525	0.67173886	2.16836424	1.10122139
RVP (constant)				
Sulfur	0.0683768			
Aromatic HC	0.15191575		-0.07537099	-0.09219416
Olefin		0.18408319		
Oxygen	-0.03295985		0.12278577	0.00122983
Oxygen (as EtOH)			-0.12295089	0.54678495
T50		0.11391774		
T90				
Benzene	-0.12025037		-0.1423482	
Model Term	Tech 4			
	Benzene	Butadiene	Formaldehyde	Acetaldehyde
Intercept	2.3824773	0.43090426	1.05886661	0.16738341
RVP (constant)	0.07392876			
Sulfur	0.09652526		-0.04135075	0.02788263
Aromatic HC	0.15517085	-0.03604344	-0.05466283	-0.05552641
Olefin	-0.02548759	0.10354089		
Oxygen		-0.02511374	0.06370091	0.02382123
Oxygen (as EtOH)			-0.09819814	0.46699012
T50	0.04666208	0.03707822		0.04314573
T90		0.09454201	0.06037698	0.06252964
Benzene	0.11689441	0.03644387		0.06148653

Model Term	Tech 5			
	Benzene	Butadiene	Formaldehyde	Acetaldehyde
Intercept	2.3824773	0.43090426	1.05886661	0.16738341
RVP (constant)	0.06514198			
Sulfur	0.09652526		-0.04135075	0.02788263
Aromatic HC	0.15517085	-0.03604344	-0.05466283	-0.05552641
Olefin	-0.02548759	0.10354089		
Oxygen		-0.02511374	0.06370091	0.02382123
Oxygen (as EtOH)			-0.09819814	0.046699012
T50	0.04666208	0.03707822		0.04314573
T90		0.09454201	0.000000	0.06252964
Benzene	0.11689441	0.03644387		0.06148653

State of California
California Environmental Protection Agency
AIR RESOURCES BOARD

Procedures for Using the California Model for California Reformulated Gasoline Blendstocks for Oxygenate Blending (CARBOB)

Adopted: April 25, 2001
Amended: August 7, 2008

Procedures for Using the California Model for California Reformulated Gasoline Blendstocks for Oxygenate Blending (CARBOB)

Table of Contents

1. INTRODUCTION AND BACKGROUND

The procedures in this document describe how to use the ARB's model for California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB). The procedures are applicable when ethanol is being blended into California Reformulated Gasoline (RFG). The procedures can be used to comply with either the Phase 2 or Phase 3 gasoline regulations. For simplicity, the procedures described in this document will be referred to as the CARBOB procedures. CARBOB is the gasoline blendstock that, when blended with ethanol, results in a finished gasoline which meets the requirements of the Phase 2 or Phase 3 California Reformulated Gasoline (RFG) Regulations. The CARBOB procedures in this document are to be used in combination with the California Procedures for Evaluating Alternative Specifications for Phase 2 Reformulated Gasoline Using the California Predictive Model or with the California Procedures for Evaluating Alternative Specifications for Phase 3 Reformulated Gasoline Using the California Predictive Model (i.e., "The Predictive Model Procedures"). The Predictive Model Procedures implement Section 2265 of the California Code of Regulations, Gasoline Subject to PM Alternative Specifications Based on the California Predictive Model. The principal element of the Predictive Model Procedures is the Phase 2 or Phase 3 predictive model which is used to evaluate the emissions equivalency of alternative complying gasolines that producers wish to produce.

Under the predictive model provisions of the Phase 2 and Phase 3 RFG regulations, the refiner inputs into the predictive model equations the fuel properties of the gasoline he is interested in producing, referred to as the predictive model candidate gasoline. The predicted emissions associated with the candidate gasoline's properties are compared to the predicted emissions for a gasoline meeting either the Phase 2 or Phase 3 limits adopted by the Air Resources Board. If the predicted emissions for the refiner's predictive model candidate gasoline are equivalent to the predicted emissions for a gasoline meeting the appropriate reformulated gasoline limits (either Phase 2 or Phase 3), the predictive model candidate gasoline is allowed to be produced as an alternative complying gasoline.

Section 2266.5, Requirements Pertaining to California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB) and Downstream Blending contains the requirements governing the production and blending of CARBOB. These CARBOB procedures implement the use of the CARBOB model, which is the principle element of these procedures. The CARBOB model is a set of equations which predict the properties of the finished gasoline (gasoline after the addition of ethanol), given the properties of the CARBOB, the properties of the ethanol blended into the CARBOB, and the ethanol content of the finished gasoline. The CARBOB properties, the ethanol properties, and the ethanol content of the finished gasoline are inputs to the CARBOB model, and the properties of the finished gasoline are outputs. The finished gasoline outputs from the CARBOB model are then input into either the Phase 2 or Phase 3 predictive model (depending on which regulations are applicable), as the predictive model candidate gasoline, and the emissions equivalency of the predictive model candidate gasoline is evaluated in accordance with the Predictive Model Procedures.

Thus, the properties of the finished predictive model candidate gasoline can be determined without actually blending the ethanol into the CARBOB.

The purposes of CARBOB model are to facilitate the enforcement of the RFG regulations and to reduce the sampling and testing demands on the refiners in ensuring that gasolines containing ethanol meet the requirements of the RFG regulations. Enforcement is facilitated by allowing the enforcement staff to sample and test CARBOB and to compare the measured CARBOB properties to the properties reported to the ARB. The enforcement staff does not necessarily have to blend into the CARBOB ethanol in order to determine if the finished gasoline complies.

2. GENERAL USE OF THE CARBOB MODEL

As discussed above, the CARBOB model is a set of equations which relate the properties of finished gasoline (gasoline containing ethanol) to the properties of the CARBOB, the properties of the ethanol blended into the CARBOB, and the amount of ethanol that is blended. The CARBOB model uses these inputs to estimate the properties of the finished gasoline, which are then input into either the Phase 2 or Phase 3 Predictive Model. The Predictive Model then evaluates whether the finished gasoline meets the emissions equivalency requirements applicable to gasolines subject to the predictive model alternative specifications of the Phase 2 or Phase 3 gasoline regulations. Figure 1 illustrates schematically how the inputs and outputs to the CARBOB model are used in combination with the Predictive Model.

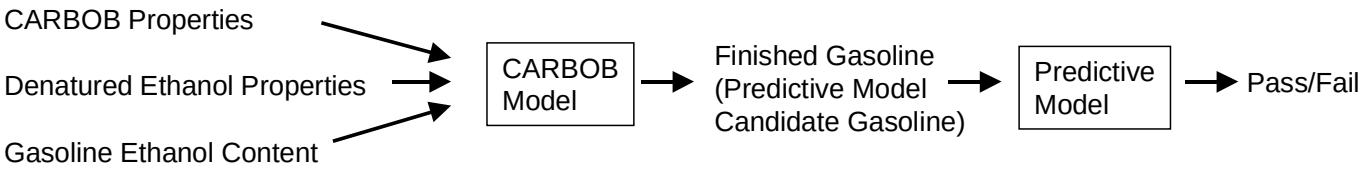
With the exception of the T50 distillation temperature and the oxygen content, the CARBOB model contains one equation for each fuel property regulated under the Phase 2 and Phase 3 RFG regulations. In the case of T50, there are two equations. There is one equation for T50 when the ethanol content of the gasoline is greater than or equal to 4.0 percent and less than 9.0 percent, and another equation when the ethanol content is from 9.0 to 10.0 percent (inclusive). If the ethanol content of the finished gasoline is less than 4.0 percent, the CARBOB model cannot be used. The CARBOB model does not contain an input for the oxygen content. The oxygen content of the predictive model candidate gasoline is input directly into either the Phase 2 or Phase 3 predictive model.

In using the CARBOB model, the user first indicates whether he intends to input into the CARBOB model proprietary values for the aromatics, olefins, sulfur, and benzene contents of the ethanol that is to blended into the CARBOB. The presence of these compounds in the ethanol generally results from the use of a denaturant. If the user does not intend to use proprietary values for the aromatics, olefins, sulfur, and benzene contents, default values are used.

The user then enters into the CARBOB model the values of the CARBOB properties, and the amount of ethanol that is to be blended into the gasoline. The CARBOB model outputs the properties of the finished (ethanol-containing gasoline). The properties of the finished gasoline are input into either the Phase 2 or Phase 3

predictive model (whichever regulatory limits are appropriate) as the properties of the predictive model candidate gasoline. The emissions equivalency of the predictive model candidate gasoline is evaluated by the predictive model in accordance with the provisions of the Predictive Model Procedures.

Figure 1
Schematic Showing the Integration of the CARBOB Model with the Predictive Model



3. CARBOB MODEL EQUATIONS

The equations which constitute the CARBOB model are shown below:

A. RVP Model

$RVP_{FG} = 1.446 + 0.961*RVP_{CARBOB}$ where,

RVP_{FG} is the RVP of the finished gasoline, in psi.
RVP_{CARBOB} is the RVP of the CARBOB, in psi.

B. T50 Models

There are two CARBOB models for T50. The first is for a finished gasoline ethanol content of greater than or equal to 4.0 percent, but less than 9.0 percent. The second is for a finished gasoline ethanol content of greater than or equal to 9.0 percent, but less than or equal to 10.0 percent.

i. Model for 4% $\leq$ EtOH < 9%

$T50_{FG} = 21.93 + 14.875*EtOH - 10.238*RVP_{CARBOB} + 0.672*T50_{CARBOB} + 0.02579*T90_{CARBOB} - 0.8313*EtOH^2 - 0.3103*RVP_{CARBOB}*EtOH + 0.06623*T50_{CARBOB}*EtOH - 0.05519*T90_{CARBOB}*EtOH + 0.03607*RVP_{CARBOB}*T90_{CARBOB}$
where,

$T50_{FG}$ is the T50 of the finished gasoline, in degrees F,
EtOH is the ethanol content of the finished gasoline, including the denaturant, in vol.%,
RVP_{CARBOB} is the RVP of the CARBOB, in psi,
$T50_{CARBOB}$ is the T50 of the CARBOB, in degrees F,
$T90_{CARBOB}$ is the T90 of the CARBOB, in degrees F.

ii. Model for 9% $\leq$ EtOH $\leq$ 10%

$T50_{FG} = 559.276 - 0.5431*RVP_{CARBOB} - 4.1884*T50_{CARBOB} - 0.3957*T90_{CARBOB} + 0.01482*T50_{CARBOB}^2 - 0.05309*T50_{CARBOB}*RVP_{CARBOB} + 0.02884*T90_{CARBOB}*RVP_{CARBOB}$
where,

$T50_{FG}$ is the T50 of the finished gasoline, in degrees F,
EtOH is the ethanol content of the finished gasoline, including the denaturant, in vol.%,

RVP_{CARBOB} is the RVP of the CARBOB, in psi,
$T50_{CARBOB}$ is the T50 of the CARBOB, in degrees F,
$T90_{CARBOB}$ is the T90 of the CARBOB, in degrees F.

Note that there is a T50 CARBOB model only for CARBOB ethanol contents greater than or equal to 4.0 percent. If the ethanol content of the CARBOB is less than 4.0 percent the CARBOB model can not be used.

C. T90 Model

$T90_{FG} = 1.493 + 0.964*T90_{CARBOB} + 0.0468*T50_{CARBOB} - 0.473*EtOH$
where,

$T90_{FG}$ is the T90 of the finished gasoline, in degrees F,
$T90_{CARBOB}$ is the T90 of the CARBOB, in degrees F,
$T50_{CARBOB}$ is the T50 of the CARBOB, in degrees F,
EtOH is the ethanol content of the finished gasoline, including the denaturant, in vol.%.

D. Aromatic Content Model

$AROM_{FG} = ((1 - (EtOH*0.01))*AROM_{CARBOB}) + (EtOH*0.01*AROM_{EtOH})$
where,

$AROM_{FG}$ is the aromatic content of the finished gasoline, in vol.%,
EtOH is the ethanol content of the finished gasoline, including the denaturant, in vol.%,
$AROM_{CARBOB}$ is the aromatic content of the CARBOB, in vol.%,
$AROM_{EtOH}$ is the aromatic content of the ethanol, in vol.%.

E. Olefin Content Model

$OLEF_{FG} = ((1 - (EtOH*0.01))*OLEF_{CARBOB}) + (EtOH*0.01*OLEF_{EtOH})$
where,

$OLEF_{FG}$ is the olefin content of the finished gasoline, in vol.%,
EtOH is the ethanol content of the finished gasoline, including the denaturant, in vol.%,
$OLEF_{CARBOB}$ is the olefin content of the CARBOB, in vol.%,
$OLEF_{EtOH}$ is the olefin content of the ethanol, in vol.%.

F. Benzene Content Model

$BENZ_{FG} = ((1 - (EtOH*0.01))*BENZ_{CARBOB}) + (EtOH*0.01*BENZ_{EtOH})$
where,

$BENZ_{FG}$ is the benzene content of the finished gasoline, in vol.%,
EtOH is the ethanol content of the finished gasoline, including the denaturant, in vol.%,
$BENZ_{CARBOB}$ is the benzene content of the CARBOB, in vol.%,
$BENZ_{EtOH}$ is the benzene content of the ethanol, in vol.%.

G. Sulfur Model

$SULF_{FG} = \{((1- (EtOH*0.01))*SULF_{CARBOB}*0.718) + (EtOH*0.01*SULF_{EtOH}*0.788)\} / \{((1-(EtOH*0.01))*0.718) + (EtOH*0.01*0.788)\}$ where,

$SULF_{FG}$ is the sulfur content of the finished gasoline, in ppm,
EtOH is the ethanol content of the finished gasoline, including the denaturant, in vol.%,
$SULF_{CARBOB}$ is the sulfur content of the CARBOB, in ppm by wt.,
$SULF_{EtOH}$ is the sulfur content of the ethanol, in ppm by wt.

4. DETAILED APPLICATION OF THE CARBOB MODEL EQUATIONS

This section will provide a step-by-step explanation of the how the CARBOB model equations are used and how the outputs from the CARBOB model are input into the Predictive Model equations.

The first step in the use of the CARBOB model is for the user to specify the properties of the ethanol that is to blended into the CARBOB. The ethanol properties to be specified are: 1) the aromatic content (vol.%), 2) the olefin content (vol.%), 3) the sulfur content (wt. ppm), and 4) the benzene content (vol.%). If the user does not specify values for the ethanol properties, the CARBOB model uses default property values. The default property values are shown in Table 1 below. If the user specifies values for the ethanol properties, they are to be specified to the same number of decimal places as is shown for the default properties.

Table 1
Default Ethanol Properties Values Used in the CARBOB Model

Property	Default Property
Aromatic content	1.7 vol.%
Olefin content	0.5 vol.%
Sulfur content	10 ppmw
Benzene content	0.06 vol.%

After the user specifies the ethanol properties (or elects to use the default ethanol property values), he specifies the values of the properties of the CARBOB and the ethanol content (including the denaturant) of the finished gasoline. The values of the CARBOB properties and ethanol content are specified to the number of decimal places shown in Table 2.

Table 2
Fuel Properties Specified in CARBOB Model

Fuel Property	Units	Decimal Places
Reid vapor pressure (RVP)	psi, max.	0.01
T50 Distilation Temperature (T50)	deg. F, max.	1.0
T90 Distillation Temperature (T90)	deg. F, max.	1.0
Aromatics Content	vol.%, max.	0.1
Olefin Content	vol.%, max.	0.1
Ethanol Content	vol.%, max.	0.1
Sulfur Content	ppmw, max.	1.0
Benzene Content	vol.%, max.	0.01

The user then uses the CARBOB model equations shown in Section 3 above and the values for each CARBOB property, ethanol property, and the ethanol content of the finished gasoline, to compute, for each property for which there is a CARBOB model, the corresponding property for the finished gasoline. The value for each property of the finished gasoline is then input into either the Phase 2 or Phase 3 predictive model as the predictive model candidate gasoline. The use of the Phase 2 or Phase 3 predictive model is dictated by which regulations are in effect or applicable to the user at the time. The applicable Predictive Model then evaluates the emissions equivalency of the predictive model candidate gasoline in accordance with the process described in the Phase 2 and Phase 3 Predictive Model Procedures.

If the user intends to produce gasoline in which at least one property will comply with the predictive model averaging compliance option, and the user is establishing a DAL for the CARBOB in accordance with section 2266.5(a)(5)(B), the CARBOB model must be used to calculate the designated alternative limit (DAL) for the final blend of oxygenated gasoline.

For the gasoline aromatic content, olefin content, benzene content, and sulfur content, the DAL for the final blend of oxygenated gasoline is calculated directly from the CARBOB models for these properties by inputting into the CARBOB models for these properties the DAL for the CARBOB. The CARBOB model prediction is the DAL for the final blend of oxygenated gasoline.

The methodology described above is also used in calculating the T50 and T90 DALs for final blends of oxygenated gasoline, with one exception. This exception occurs if a producer is producing gasoline in which the T50 will comply with a predictive model flat limit and the T90 will comply with a predictive model averaging limit, or the T50 will comply with a predictive model averaging limit and the T90 will comply with a predictive model flat limit. In these cases, the DAL for the final blend of oxygenated gasoline is calculated by inputting into the CARBOB model the value of the CARBOB DAL for the property (either T50 or T90) which is being produced to the predictive model averaging limit, and inputting into the CARBOB model the flat limit of the CARBOB property (T50 or T90) that is being produced to the predictive model flat limit. The CARBOB model prediction is the DAL for the final blend of oxygenated gasoline for the property being produced under the predictive model averaging compliance option.

A minimum RVP requirement for CARBOB would be in effect during the non-RVP control period (i.e., the time in which the RVP limits specified in Section 2262 are not in effect). The purpose of this "wintertime" RVP specification is different from the purpose of the summertime RVP requirement for CARBOB or final blend of oxygenated gasoline. The purpose of the non-RVP control period minimum RVP requirement is to ensure that the T50 of a final blend of oxygenated gasoline is not greater than the value predicted by the CARBOB model. The minimum RVP requirement for the non-RVP control period arises as a consequence of the RVP term in the T50 CARBOB model. The T50 CARBOB model predicts that the T50 of a final blend of oxygenated gasoline decreases as the RVP of the CARBOB increases. Thus, while there are no basic flat or average RVP limits for CARBOB or gasoline that is not subject to the maximum RVP standards in section 2262, it is still necessary to specify the RVP of the CARBOB during the non-RVP control period in order to make a prediction for the T50 of the final blend of oxygenated gasoline. The RVP value that is used in making this prediction becomes a minimum allowable RVP for the particular blend of CARBOB during the non-RVP control period. That is, during the non-RVP control period, the CARBOB produced by the refiner is required to have an RVP greater than or equal to the value used in the T50 CARBOB model. This ensures that the final blend of oxygenated gasoline has a T50 less than or equal to that predicted by the T50 CARBOB model.

Shown in Table 3 on the next page is a worksheet which includes a step-by-step process to illustrate the use of the CARBOB procedures and to assist the user in using the CARBOB model. The worksheet in Table 3 assumes that the user is complying with the Phase 3 regulations, but the same process would be used if the user were complying with the Phase 2 regulations. Only Step 5 in the process shown in Table 3 would be different if the user were complying with the Phase 2 gasoline regulations. In

that case, the user would compare his predictive model candidate gasoline to the applicable Phase 2 limits instead of the Phase 3 limits.

Table 3
Worksheet for Computing Finished Gasoline Properties from CARBOB Properties

Step 1: Do you elect to use the evaporative emissions model element of the Phase 3 Predictive Model? Yes (Y) or No (N)

Step 2: Specify the properties of the ethanol, or use the default values in the table below.

Property	Specified Value	Default Value
Aromatic content (vol.%)		1.7
Olefin content (vol.%)		0.5
Sulfur content (ppmw)		10
Benzene content (vol.%)		0.06

Step 3: Specify the ethanol content, including the denaturant, in volume percent, of the finished gasoline. Ethanol content = _____ vol. percent.

Step 4: Enter in the table below the values of the CARBOB properties. For these CARBOB property values, and the ethanol properties specified in Step 2, and the ethanol content specified in Step 3, use the CARBOB model equations shown in Section 3 to compute the properties of the finished gasoline. Enter both the CARBOB values and the predicted finished gasoline values in the table below.

Property	CARBOB Value	Predicted Finished Gasoline Value[1]
RVP (psi)		
T50 (deg. F)		
T90 (deg. F)		
Aromatics (vol.%)		
Oxygen as Ethanol (max.) (vol.%)	Not Specified by User	
Oxygen as Ethanol (min.) (vol.%)	Not Specified by User	
Sulfur (ppmw)		
Benzene (vol.%)		

1 – The maximum and minimum oxygen values are specified by the user and are not predicted by the CARBOB model.

Step 5: Complete Table 7 of the Phase 3 Predictive Model Procedures by entering into column 2 (Candidate Fuel Specifications) of Table 7 of the Phase 3 Predictive Model Procedures the predicted finished gasoline property values from Step 4. For convenience, Table 7 of the Phase 3 Predictive Model Procedures is shown on the next page. Proceed with the evaluation of the candidate fuel in accordance with the requirements specified in the Phase 3 predictive model Procedures.

Table 4
(Table 7 of Predictive Model Procedures)
Optional Worksheet for Candidate and Reference Fuel Specifications

Does the applicant wish to certify a fuel containing ethanol? YES ___ NO ___

If the above question is answered yes, then the flat RVP limit is 7.00 psi and the RVP cap is 7.20 psi. If the above question is answered no, then 6.90 psi is the flat RVP limit for the candidate fuel RVP specification.

Fuel Property	Candidate Fuel[1]: Specifications	Compliance Option: Flat or Average	**Reference Fuel: Phase 3 RFG Specifications** (Circle Option Chosen)	
			Flat	Average
RVP		Flat	6.90[5] / 7.00	None
Sulfur			20	15
Benzene			0.80/1.00[6]	0.70
Aromatic			25.0/35.0[6]	22.0
Olefin			6.0	4.0
Oxygen[2] (Total)	(min)	Flat-Range	(min)	None
	(max)		(max)	
Oxygen[3] (as MTBE)	(min)	Not Applicable	Not Applicable	None
	(max)			
Oxygen[4] (as EtOH)	(min)	Not Applicable	Not Applicable	None
	(max)			
T50			213/220[6]	203
T90			305/312[6]	295

note: Footnotes are on the next page

Footnotes for Table 4

[1] The fuel property value must be within or equal to the cap limit.

[2] If the oxygen content range for the candidate fuel is 1.8 and 2.2, the candidate fuel and reference fuel oxygen value used in the predictive model equation is 2.0. For all other cases, see Table 6, Candidate and Reference Specifications for Oxygen.

[3] The oxygen content (as MTBE) is reported because the hot soak evaporative benzene emissions model includes an MTBE content term (See VIII.A.2).

[4] The oxygen content (as EtOH) is reported because the exhaust formaldehyde and the exhaust acetaldehyde models include EtOH content terms for the predictions for the candidate fuel specifications -(See VI.A.1.c & d., VI.A.2.c & d., VI.A.3.c & d.). The EtOH content term is not included in the exhaust formaldehyde and acetaldehyde predictions for the reference fuel specifications because it is assumed that, for the reference fuel specifications, MTBE is the oxygenate used to meet the oxygen requirement.

[5] If the applicant wishes to certify a fuel containing ethanol, then the flat RVP limit is 7.00. If the applicant wishes to certify a fuel that does not contain ethanol, then the flat limit for RVP is 6.90 psi. In either circumstance, the cap limit for RVP is 7.20 psi. The exhaust models contain an RVP term, but this term has been made constant by fixing the RVP for both the reference and candidate fuels at 7.00 psi in the calculation of the standardized RVP values used in the exhaust emissions equations. This fixing of the RVP takes RVP out of the exhaust models as a fuel property which effects exhaust emissions.

[6] The higher value is the small refiner CaRFG flat limit for qualifying small refiners only, as specified in section 2272.

Table 3 shows that the oxygen content is not specified in the CARBOB model by the user. The user specifies only the ethanol content of the finished gasoline, which is used in the CARBOB model equations to calculate the properties of the finished gasoline. As shown by the CARBOB model equations shown in Section 3, the ethanol content of the finished gasoline is used in all the CARBOB model equations except RVP.

The oxygen content of the finished gasoline is specified by the user when using either the Phase 2 or the Phase 3 predictive model. The user specifies in the predictive model an oxygen content range. The oxygen content range is specified when all other properties of the predictive model candidate fuel are specified, as shown in Table 4 above. For a more detailed discussion of the specification of the oxygen content range for predictive model candidate fuels, see the Predictive Model Procedures document.

After the CARBOB model predictions have been made and entered into the predictive model, all evaluations of the finished gasoline predictive model candidate fuel are made in accordance with the provisions of the Predictive Model Procedures.