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**

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Note: This is a wholly new document adopted by the Air Resources Board.

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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(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

B.   Synopsis of Procedure

The predictive model is used to compare the exhaust emissions predicted for gasoline meeting the Phase 2 RFG specifications (reference specifications) to the exhaust emissions predicted for gasoline meeting the alternative gasoline specifications (candidate specifications).

The predictive model is made up of several sub-models. The sub-models are equations which relate gasoline specifications for certain properties to the exhaust emissions that result when the gasoline is burned in a motor vehicle. The gasoline properties included in the model are those properties that are regulated by the California Phase 2 RFG regulations (See Table 1).

Twelve separate sub-models have been developed for six pollutants (NOx, HC, benzene, 1,3-butadiene, formaldehyde, and acetaldehyde) and two sub-models, per pollutant, for each vehicle emissions technology "Tech" class (Tech 3 and Tech 4). The predicted emissions for each Tech class are adjusted using Tech class emission-weighting factors for NOx and HC. Toxic emissions (benzene, 1,3-butadiene, formaldehyde, and acetaldehyde) are adjusted using VMT (vehicle miles traveled) weighting factors and a potency weighting factor.

The sub-models are used to predict the emissions from the Phase 2 RFG specifications and the alternative specifications. The emissions are expressed in the units identified in Table 2. If, for each pollutant (NOx, HC, and potency-weighted toxics), the percent change in emissions between the candidate specifications and the reference Phase 2 RFG specifications, is equal to or less than 0.04%, then the candidate specifications are deemed acceptable as equivalent to Phase 2 RFG. If the percent change in emissions between the candidate specifications and the reference Phase 2 RFG specifications, is equal to or greater than 0.05%, then the candidate specifications are deemed unacceptable and may not be a substitute for Phase 2 RFG. [Note: All final values of the percent change in emissions shall be reported to the nearest hundreth 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 2 Reformulated Gasoline Using the California Predictive Model.

2.   **Alternative 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)** 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 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 2262.1 (a), 2262.2 (a), 2262.3 (a), 2262.4 (a), 2262.5 (a) and (b), 2262.6 (a), and 2262.7 (a).

10. **EMFAC/BURDEN 7F** means the motor vehicle emission inventory and emissions calculation system maintained by the ARB.

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

12. **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.

13. **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.

14. **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.

15. **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.

16. **Phase 2 reformulated gasoline (Phase 2 RFG)** means gasoline meeting the flat or averaging limits of the Phase 2 RFG regulations.

17. **Potency-weighted 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.

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

19. **Reference fuel or reference specification** means a gasoline meeting the flat or average specifications for Phase 2 RFG.

20. **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.

21. **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.

22. **Technology class (Tech 3, Tech 4)** means a classification of vehicles by model year based on what technology is used to control gasoline exhaust emissions.

23. **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.

24. **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.

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

II.   VEHICLE TECHNOLOGY CLASS AND WEIGHTING FACTORS

A.   Vehicle Technology Classes

For the purpose of these procedures, sub-models have been developed for two 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 two 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

B.   Emission-weighting Factors

Emission-weighting factors are used to weight the relative contribution of the model-predicted NOx and HC emissions in each Technology class. These weightings represent the average fractional contribution that vehicles in the particular Tech class make to the total on-road motor vehicle emissions of a particular pollutant from gasoline-fueled light duty vehicles in the years 1996, 2000, and 2005. These values were calculated using the information in EMFAC/BURDEN 7F. The emission-weighting factors (EWF) are shown in Table 4 and are used in the evaluation of NOx and HC emissions.

Table 4
Emission-weighting Factors

Pollutant	Tech 3	Tech 4
NOx	0.174	0.826
HC	0.198	0.802

C.   VMT Weighting Factors

Vehicle miles traveled (VMT) weighting factors are used to weight the relative contribution of the model-predicted toxic air contaminant emissions in each technology class. These weightings represent the average fractional contribution to VMT that vehicles in the particular Tech class make to the total VMT from vehicles in all technology classes used in the model. The values were

calculated by identifying the VMT fraction(s) for Tech class 3 and 4 vehicles for 1996, 2000, and 2005, summing these values by Tech class, and calculating the arithmetic average. The VMT data were obtained from EMFAC/BURDEN 7F. The VMT weighting factors (VMTWFs) are shown in Table 5 and are used in the evaluation of toxic air contaminants.

Table 5

Vehicle Miles Traveled Weighting Factors (VMTWFs)

Pollutant	Tech 3	Tech 4
Benzene	0.089	0.911
1,3-Butadiene	0.089	0.911
Formaldehyde	0.089	0.911
Acetaldehyde	0.089	0.911

III. GENERAL EQUATIONS FOR CALCULATING PERCENT CHANGE IN EMISSIONS

A. Summary and Explanation

♦ 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 2 RFG reference specification is identified, for each property, using the compliance option selected for the corresponding candidate specification. (See III.B.)

♦ The selected candidate specifications and the comparable Phase 2 RFG reference specifications are inserted into the predictive model equations to determine the predicted candidate and reference emissions by Tech Class. (See III.C.)

♦ For NOx and HC, the ratio of the predicted emissions for the candidate specifications to the predicted emissions for the reference 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 percent change in emissions. The resulting values represent the percent change in NOx or HC emissions between the candidate specifications and reference specifications. (See III.D.)

♦ For toxic air contaminants, the predicted emissions for the candidate specifications (for each pollutant and each Tech Class) are VMT weighted and potency-weighted. The VMT/potency-weighted sums for the candidate specifications are divided by the VMT/potency-weighted sums for the reference specifications. This ratio is reduced by 1 and then multiplied by 100. The resulting value represents the percent change in potency-weighted toxic emission between the candidate specifications and reference specifications. (See III.D.)

B.   **Selection by Applicant of Candidate and Reference Specifications**

The applicant shall select a candidate specification and for each property shall identify whether the specification represents a flat limit or an averaging limit. The Phase 2 RFG reference specifications are identified using, for each property, the compliance option selected for the corresponding candidate specification. Table 7 provides an optional worksheet to assist the applicant in selecting the candidate and reference specifications.

1.   Identify the value of the candidate specifications for each fuel property and insert the values into Table 7. The candidate specifications may have any value for 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. 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. The RVP value for the reference and candidate specifications is always 7.00. The appropriate values for oxygen content are shown in Table 6.

Table 6
Candidate and Reference Specifications for Oxygen

Oxygen Content for Candidate Fuel		Number of Reference vs Candidate Comparisons Required	Values to be Used in Comparison in Equations	
minimum	maximum		Candidate	Reference
≥ 1.8, ≤ 2.2	≥1.8, ≤ 2.2	1	2.0	2.0
≥ 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	> 2.2	2	minimum	2.0
			maximum	2.0

2. Identify for each specification for a property other than RVP and oxygen whether the compliance option will represent a flat limit or an averaging limit.

3. Identify the reference specifications based on the compliance options selected in step 2. 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. Write in the appropriate reference specifications for oxygen content based on the information in Table 6.

Example:
    If you elect to meet a sulfur limit of 20 for the candidate fuel and elect to comply with a flat limit, the reference fuel sulfur limit would be 40. However, if you elect to meet a sulfur limit of 20 on average, the reference fuel sulfur limit would be 30.

Table 7
Optional Worksheet for Candidate and Reference Fuel Specifications

Fuel Property	Candidate Fuel[1]: Specifications	Compliance Option: Flat or Average	Reference Fuel: Phase 2 RFG Specifications (Circle Option Chosen)	
			Flat	**Average**
RVP[2]	7.00	Flat	7.00	None
Sulfur			40	30
Benzene			1.00	0.80
Aromatic			25.0	22.0
Olefin			6.0	4.0
Oxygen[3]	(min)	Flat-Range	(min)	None
	(max)		(max)	
T50			210	200
T90			300	290

[1]   The fuel property value must be within or equal to the cap limit.
[2]   The candidate fuel RVP value is always 7.00.
[3]   If the oxygen content range for the candidate fuel is $\geq$ 1.8 and $\leq$ 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.

C.   General Equations for Calculating 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 emissions of the candidate and reference 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 inverse of the natural logarithm.

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

intercept represents the average vehicle effect for a particular Tech class and a particular pollutant. The intercepts are provided in Table 11, Coefficients for NOx and HC Equations, and Table 12, 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 11, Coefficients for NOx and HC Equations, and Table 12, Coefficients for Toxics.

standardized fuel property is defined as:

standardized fuel property =

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

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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 and V. A. 2.

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 10, 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.

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

To calculate the percent change of NOx and HC 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 and HC. These weighted ratios are summed. The sum is reduced by 1 and multiplied by 100 to give the percent change in emission for NOx or HC pollutant.

To calculate the percent change of toxic pollutant emissions, the emissions for the candidate and reference specifications are multiplied by the VMT weighting factors for Technology class 3 and 4 vehicles. The sum of the VMT-weighted emission estimates is multiplied by the appropriate potency-weighting factor. The sum of potency-weighted emissions for the candidate specification is divided by the sum of the potency-weighted emissions for the reference specifications. This quotient is reduced by 1 and multiplied by 100.

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

% Change in NOx and HC Emissions:

%CE = change in emissions =

$$\left(\left[\frac{Y_{TECH\,3-CAND}}{Y_{TECH\,3-REF}} \left(EWF_{3q} \right) \right] + \left[\frac{Y_{TECH\,4-CAND}}{Y_{TECH\,4-REF}} \left(EWF_{4q} \right) \right] -1 \right) 100$$

where

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

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

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

<u>% Change in Potency-weighted Toxic (PWT) Emission:</u>

Step 1. Calculation of VMT and potency-weighted emissions for candidate and reference specifications

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

$$\sum \left[\left(\left\lfloor (Y_{TECH3q\text{-}CAND}) \times (VMTWF_3) \right\rfloor + \left\lfloor (Y_{TECH4q\text{-}CAND}) \times (VMTWF_4) \right\rfloor \right) \times (PWF_q) \right]$$

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

$$\sum \left[\left(\left\lfloor (Y_{TECH3q\text{-}REF}) \times (VMTWF_3) \right\rfloor + \left\lfloor (Y_{TECH4q\text{-}REF}) \times (VMTWF_4) \right\rfloor \right) \times (PWF_q) \right]$$

where

$(y_{Tech\,3q})$ and $(y_{Tech\,4q})$ are the emissions in milligrams per mile for each toxic air contaminant for Tech class 3 or 4.

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

$VMTWF_3$ and $VMTWF_4$ are the VMT weighting factors for Tech class 3 and Tech class 4 vehicles, 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.

Step 2.   Calculation of percent change in potency-weighted toxic (PWT) emissions.

% CE $_{PWT}$ = percent change in the sum of the PWT emissions =

$$\left| \frac{E_{PWT-CAND}}{E_{PWT-REF}} - 1 \right| x \ (100)$$

where

E$_{PWT-CAND}$ is the sum of PWT emissions for candidate specifications from Step 1 above.

E$_{PWT-REF}$ is the sum of PWT emissions for reference specifications from Step 1 above.

Table 8
Toxic Air Contaminant Potency-weighting Factors

Pollutant	Potency-weighting Factor
Benzene	0.17
1,3-Butadiene	1
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	{-0.108411656	+
Sulfur	$(0.01785987) \dfrac{(\underline{\text{SULFUR - 193.574245}})}{130.374657}$	+
Aromatic HC	$(0.05428291) \dfrac{(\underline{\text{AROM - 30.967805}})}{9.491877}$	+
Olefin	$(0.02292342) \dfrac{(\underline{\text{OLEF - 8.34672}})}{5.873768}$	+
Oxygen	$(0.01439508) \dfrac{(\underline{\text{OXY - 0.912512}})}{1.249609}$	+
T50	$(-0.01161378) \dfrac{(\underline{\text{T50 - 211.338086}})}{17.374327}$	+
T90	$(0.00341764) \dfrac{(\underline{\text{T90 - 315.839826}})}{25.694736}$	+
T50T90	$(0.00857682) \dfrac{(\underline{\text{T50 - 211.338086}})}{17.374327} \dfrac{(\underline{\text{T90 - 315.839826}})}{25.694736}$	+

AROT90   (-0.0097818) (ARO - 30.967805) (T90 - 315.839826) $\Big\}$
                              9.491877   25.694736

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	{-0.6826367	+
Sulfur	(0.050086115) (SULFUR - 174.036113) 137.356549	+
Aromatic HC	(0.004154304) (AROM - 28.604566) 7.848674	+
Olefin	(0.025949698) (OLEF - 7.001772) 4.988003	+
Oxygen	(-0.008991879) (OXY - 1.266843) 1.310604	+
T50	(0.00195233) (T50 - 208.186678) 18.149553	+
T90	(-0.00820391) (T90 - 311.36879) 22.988439	+
AROOXY	(-0.00579379) (AROM - 28.604566) (OXY - 1.266843) 7.848674 1.310604	+

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OXYOXY (0.013486985) $\left(\dfrac{OXY - 1.266843}{1.310604}\right)$ $\left(\dfrac{OXY - 1.266843}{1.310604}\right)$ $\Big\}$

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

$$OXYGEN_{(LIN)} = 0.677 + 0.0358669 \, AROM$$

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

B.   Percent Change in NOx Emissions

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

$$\%CE = \left[\left(\left| \frac{(Y_{TECH\ 3-CAND})}{(Y_{TECH\ 3-REF})} \ x\ EWF_{3-NOx} \right| + \left| \frac{(Y_{TECH\ 4-CAND})}{(Y_{TECH\ 4-REF})} \ x\ EWF_{4-NOx} \right| \right) - 1 \right] x\ 100$$

where

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

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

NOx emissions for Tech 3 are calculated according to the equations in section IV. A. 1.

NOx emissions for Tech 4 are calculated according to the equations in section IV. A. 2.

EWF_{3-NOx} and EWF_{4-NOx} are the emission-weighting factors for NOx as shown in Table 4.

V. HYDROCARBONS (HC) EXHAUST EMISSIONS CALCULATIONS

A. 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. 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	{-0.80726502	+
Sulfur	(0.001933575) (SULFUR - 193.574245) 130.374657	+
Aromatic HC	(-0.03844685) (AROM - 30.967805) 9.491877	+
Olefin	(-0.02100516) (OLEF - 8.34672) 5.873768	+
Oxygen	(-0.02735656) (OXY - 0.912512) 1.249609	+
T50	(0.056534360) (T50 - 211.338086) 17.374327	+
T90	(0.017858355) (T90 - 315.839826) 25.694736	+

SULARO   (-0.04053717) $\dfrac{\text{(SULFUR - 193.574245)}}{130.374657}$ $\dfrac{\text{(AROM - 30.967805)}}{9.491877}$ +

AROT90   (0.018225949) $\dfrac{\text{(AROM - 30.967805)}}{9.491877}$ $\dfrac{\text{(T90 - 315.839826)}}{25.694736}$ $\Big\}$

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.   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	{-1.15555
Sulfur	(0.116903682) $\dfrac{\text{(SULFUR - 174.036113)}}{137.356549}$
Aromatic HC	(0.001368326) $\dfrac{\text{(AROM - 28.604566)}}{7.848674}$
Olefin	(-0.0068737) $\dfrac{\text{(OLEF - 7.001772)}}{4.988003}$
Oxygen	(-0.01035001) $\dfrac{\text{(OXY - 1.266843)}}{1.310604}$
T50	(0.076436841) $\dfrac{\text{(T50 - 208.186678)}}{18.149553}$
T90	(0.038947849) $\dfrac{\text{(T90 - 311.36879)}}{22.988439}$
AROARO	(-0.01197286) $\dfrac{\text{(AROM - 28.604566)}}{7.848674}$ $\dfrac{\text{(AROM - 28.604566)}}{7.848674}$

(each row ends with +)

AROT90   (0.012076013) $\dfrac{(AROM - 28.604566)}{7.848674}$ $\dfrac{(T90 - 311.36879)}{22.988439}$ +

OXYT90   (0.015107193) $\dfrac{(OXY - 1.266843)}{1.310604}$ $\dfrac{(T90 - 311.36879)}{22.988439}$ +

T50T50   (0.025807977) $\dfrac{(T50 - 208.186678)}{18.149553}$ $\dfrac{(T50 - 208.186678)}{18.149553}$ +

T90T90   (0.018209586) $\dfrac{(T90 - 311.36879)}{22.988439}$ $\dfrac{(T90 - 311.36879)}{22.988439}$ $\Big\}$

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

   If the value for the candidate T50 specification in the Table 7 worksheet is less that 181, 181 is the value for T50.

   If the value for the candidate T50 specification in the Table 7 worksheet is greater than or equal to 181, 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, the T90 $_{(LIN)}$ value is the value for T90 where T90 $_{(LIN)}$ is calculated as follows:

    T90 $_{(LIN)}$ = 323.8 - 0.9712 AROM - 7.27598 OXY

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

B.   Percent Change in HC Emissions

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

$$\%CE = \left| \left(\left| \frac{(Y_{TECH\,3-CAND})}{(Y_{TECH\,3-REF})} \; x \; EWF_{3-VOC} \right| + \left| \frac{(Y_{TECH\,4-CAND})}{(Y_{TECH\,4-REF})} \; x \; EWF_{4-VOC} \right| \right) - 1 \right| x\,100$$

where

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

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

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

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

EWF_{3-HC} and EWF_{4-HC} are the emission-weighting factors for HC as shown in Table 4.

VI. 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 = $y_{Tech\ 3}$ =

Description	Equation	
	Exp	
intercept	{2.9937382	+
Sulfur	(0.0723141)(SULFUR - 193.574245) 130.374657	+
Aromatic HC	(0.1524752)(AROM - 30.967805) 9.491877	+
Oxygen	(-0.034762)(OXY - 0.912512) 1.249609	+
BENZ	(0.1235949)(BENZ - 1.365963) 0.444768 }	

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

Description	Equation	
	Exp	
intercept	{0.668257	+
Olefin	$(0.150707)\dfrac{(\underline{OLEF - 8.34672})}{5.873768}$	+
T90	$(0.165206)\dfrac{(\underline{T90 - 315.839826})}{25.694736}$ }	

c.   Formaldehyde mass emissions Tech 3 = y $_{Tech\ 3}$ =

Description	Equation	
	Exp	
intercept	{2.041917	+
Sulfur	(-0.18011)<u>(SULFUR - 193.574245)</u> 130.374657	+
Aromatic HC	(-0.09754)<u>(AROM - 30.967805)</u> 9.491877	+
Oxygen	(0.153291)<u>(OXY - 0.912512)</u> } 1.249609	

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

Description	Equation
	Exp
intercept	{1.041177 +

Aromatic HC $\dfrac{(-0.10224)(\underline{AROM - 30.967805})}{9.491877}$ }

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.   Mass Emissions for Tech 4

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

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

Description	Equation	
	Exp	
intercept	{2.014861	+
Sulfur	$(0.140432)\dfrac{(SULFUR - 174.036113)}{137.356549}$	+
Aromatic HC	$(0.169401)\dfrac{(AROM - 28.604566)}{7.848674}$	+
Olefin	$(0.02158)\dfrac{(OLEF - 7.001772)}{4.988003}$	+
Oxygen	$(0.022392)\dfrac{(OXY - 1.266843)}{1.310604}$	+
T50	$(0.052416)\dfrac{(T50 - 208.186678)}{18.149553}$	+
BENZ	$(0.145341)\dfrac{(BENZ - 1.092985)}{0.563303}$ }	

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

Description	Equation	
	Exp	
intercept	{-0.12765	+
Sulfur	$\dfrac{(0.060078)(SULFUR - 174.036113)}{137.356549}$	+
Aromatic HC	$\dfrac{(-0.04862)(AROM - 28.604566)}{7.848674}$	+
Olefin	$\dfrac{(0.135542)(OLEF - 7.001772)}{4.988003}$	+
T50	$\dfrac{(0.058141)(T50 - 208.186678)}{18.149553}$	+
T90	$\left.\dfrac{(0.089544)(T90 - 311.36879)}{22.988439}\right\}$	

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

Description	Equation	
	Exp	
intercept	{0.56907	+
Sulfur	$\dfrac{(-0.04472)(\underline{SULFUR - 174.036113})}{137.356549}$	+
Aromatic HC	$\dfrac{(-0.07248)(\underline{AROM - 28.604566})}{7.848674}$	+
Oxygen	$\dfrac{(0.073394)(\underline{OXY - 1.266843})}{1.310604}$	+
T90	$\left.\dfrac{(0.081896)(\underline{T90 - 311.36879})}{22.988439}\right\}$	

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

Description	Equation
	Exp

intercept $\{-0.50722$ +

Aromatic HC $\dfrac{(-0.06631)(\underline{AROM - 28.604566})}{7.848674}$ +

Oxygen $\dfrac{(0.084501)(\underline{OXY - 1.266843})}{1.310604}$ +

T50 $\dfrac{(0.08131)(\underline{T50 - 208.186678})}{18.149553}$ +

T90 $\left.\dfrac{(0.070103)(\underline{T90 - 311.36879})}{22.988439}\right\}$

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

B. Percent Change in Potency-weighted Toxic Emissions

    1.   Calculation of Percent VMT and Potency-weighted Emissions for Candidate Specifications

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

$$\left[\left(\left[\,(Y_{BZ\text{-}TECH3})\,(VMTWF_3)\,\right]+\left[(Y_{BZ\text{-}TECH4})\,(VMTWF_4)\,\right]\right)\times(PWF_{BZ})\right]+$$

$$\left[\left(\left[\,(Y_{BD\text{-}TECH3})\,(VMTWF_3)\,\right]+\left[(Y_{BD\text{-}TECH4})\,(VMTWF_4)\,\right]\right)\times(PWF_{BD})\right]+$$

$$\left[\left(\left[\,(Y_{FOR\text{-}TECH3})\,(VMTWF_3)\,\right]+\left[(Y_{FOR\text{-}TECH4})\,(VMTWF_4)\,\right]\right)\times(PWF_{FOR})\right]+$$

$$\left[\left(\left[\,(Y_{ACE\text{-}TECH3})\,(VMTWF_3)\,\right]+\left[(Y_{ACE\text{-}TECH4})\,(VMTWF_4)\,\right]\right)\times(PWF_{ACE})\right]$$

where

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

    y $_{BZ\text{-}TECH}$ is the benzene emission for Tech 3 or Tech 4
    y $_{BD\text{-}TECH}$ is the 1,3-butadiene emission for Tech 3 or Tech 4
    y $_{FOR\text{-}TECH}$ is the formaldehyde emission for Tech 3 or Tech 4
    y $_{ACE\text{-}TECH}$ is the acetaldehyde emission for Tech 3 or Tech 4

    VMTWF$_3$ and **VMTWF$_4$** are the VMT weighting factors for Tech class 3 and Tech class 4 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 Percent VMT and Potency-weighted Emissions for Reference Specifications

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

$$\left[\left(\left[\left(y_{BZ-TECH3}\right)\left(VMTWF_3\right)\right]+\left[\left(y_{BZ-TECH4}\right)\left(VMTWF_4\right)\right]\right)x\left(PWF_{BZ}\right)\right]+$$

$$\left[\left(\left[\left(y_{BD-TECH3}\right)\left(VMTWF_3\right)\right]+\left[\left(y_{BD-TECH4}\right)\left(VMTWF_4\right)\right]\right)x\left(PWF_{BD}\right)\right]+$$

$$\left[\left(\left[\left(y_{FOR-TECH3}\right)\left(VMTWF_3\right)\right]+\left[\left(y_{FOR-TECH4}\right)\left(VMTWF_4\right)\right]\right)x\left(PWF_{FOR}\right)\right]+$$

$$\left[\left(\left[\left(y_{ACE-TECH3}\right)\left(VMTWF_3\right)\right]+\left[\left(y_{ACE-TECH4}\right)\left(VMTWF_4\right)\right]\right)x\left(PWF_{ACE}\right)\right]$$

where

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

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

VMTWF$_3$ and **VMTWF$_4$** are the VMT weighting factors for Tech class 3 and Tech class 4 vehicles, respectively. These values are shown in Table 5.

PWF$_q$ is the potency-weighting factor for toxic pollutant q provided in Table 8.

3. Calculation of Percent Change in Emissions

% CE $_{\text{PWT}}$ = percent change in potency-weighted toxic emissions

$$\%CE_{PWT}=\left|\frac{E_{PWT-CAND}}{E_{PWT-REF}}-1\right|x\left(100\right)$$

VII.   DETERMINATION OF ACCEPTABILITY

If, for each pollutant (NOx, HC, and potency-weighted toxics), the percent change in emissions between the candidate specifications and the reference Phase 2 RFG specifications is equal to or less than 0.04%, then the candidate specifications are deemed acceptable as an alternative to Phase 2 RFG. The candidate specifications must pass for all three categories -- NOx, HC, and PWT -- to be acceptable as an alternative Phase 2 RFG formulation;

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

If the percent change in emission between the candidate specifications and the reference Phase 2 RFG specifications is equal to or greater than 0.05%, then the candidate specifications are deemed unacceptable and <u>may not</u> be a substitute for Phase 2 RFG. [Note: All final values of the percent change in emissions shall be reported to the nearest hundreth 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.

VIII. 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 9, Alternative Specifications for Phase 2 RFG Using the California Predictive Model Notification has been provided as an example of the minimum information required.

Table 10
Standardization of Fuel Properties - Mean and Standard Deviation

Fuel Property	Tech 3		Tech 4	
	Mean	Std. Dev.	Mean	Std. Dev.
RVP	8.651419	0.580438	8.707348	0.52813
Sulfur	193.574245	130.374657	174.036113	137.356549
Aromatic HC	30.967805	9.491877	28.604566	7.848674
Olefin	8.34672	5.873768	7.001772	4.988003
Oxygen	0.912512	1.249609	1.266843	1.310604
T50	211.338086	17.374327	208.186678	18.149553
T90	315.839826	25.694736	311.36879	22.988439
Benzene	1.365963	0.444768	1.092985	0.563303

Table 11
Coefficients for NOx and HC Equations

Pollutant Emission	Tech 3		Tech 4	
	NOx	HC	NOx	HC
Intercept	-0.108411656	-0.80726502	-0.6826367	-1.15555
RVP				
Sulfur	0.01785987	0.001933575	0.050086115	0.116903682
Aromatic HC	0.05428291	-0.03844685	0.004154304	0.001368326
Olefin	0.02292342	-0.02100516	0.025949698	-0.0068737
Oxygen	0.01439508	-0.02735656	-0.008991879	-0.01035001
T50	-0.01161378	0.056534360	0.00195233	0.076436841
T90	0.00341764	0.017858355	-0.00820391	0.038947849
AROARO				-0.01197286
AROOXY			-0.00579379	
AROT90	-0.0097818	0.018225949		0.012076013
OXYOXY			0.013486985	
OXYT90				0.015107193
T50T50				0.025807977
T50T90	0.00857682			
T90T90				0.018209586
SULARO		-0.04053717		

Table 12
Coefficients for Toxics Equations

Pollutant Emission	Tech 3			
	Benzene	**Butadiene**	**Formaldehyde**	**Acetaldehyde**
Intercept	2.9937382	0.668257	2.041917	1.041177
RVP				
Sulfur	0.0723141		-0.18011	
Aromatic HC	0.1524752		-0.09754	-0.10224
Olefin		0.150707		
Oxygen	-0.034762		0.153291	
T50				
T90		0.165206		
Benzene	0.1235949			

Pollutant Emission	Tech 4			
	Benzene	**Butadiene**	**Formaldehyde**	**Acetaldehyde**
Intercept	2.014861	-0.12765	0.56907	-0.50722
RVP				
Sulfur	0.140432	0.060078	-0.04472	
Aromatic HC	0.169401	-0.04862	-0.07248	-0.06631
Olefin	0.02158	0.135542		
Oxygen	0.022392		0.073394	0.084501
T50	0.052416	0.058141		0.08131
T90		0.089544	0.081896	0.070103
Benzene	0.145341			

$$HC_{DR} = Exp(-3.81926 + 0.23439*RVP)$$

$$HC_{HS} = Exp(-8.05257 + 1.15040*RVP - 0.0489*RVP*RVP$$

$$HS_{RL} = 0.46125 - 0.14057*RVP + 0.13298*RVP*RVP$$

$$(Benz./HC)_{DR} = Benzene*($$