Speciation Profiles and Toxic Emission Factors for Nonroad Engines

DRAFT

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Prepared by:

Office of Transportation and Air Quality
U.S. Environmental Protection Agency
2000 Traverwood Drive
Ann Arbor, MI 48105

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1.0 Introduction

Air pollution inventory modelers have traditionally estimated emissions from nonroad, or non-highway, engines and equipment by using EPA's NONROAD model. With the release of MOVES2014, users are able to model emissions from both onroad highway vehicles and nonroad engines and equipment within the same interface.[A] However, MOVES2014 did not estimate emissions of nonroad toxics or speciated hydrocarbons. This capability has been added to MOVES2014a. This document describes the data used to generate speciation profiles and emission rates for toxic compounds emitted from nonroad engines and equipment in the MOVES2014a database and model.

Substantial updates to nonroad air toxic emission factors, historically estimated from NMIM, are provided by incorporating data from several test programs on speciated emissions from gasoline and diesel engines and equipment.

This document details the research and development behind how MOVES2014a estimates air toxic emissions for nonroad engines and equipment run on conventional gasoline without ethanol (E0) and gasoline blended with 10% ethanol (E10) as well as diesel fuel, compressed natural gas (CNG), and liquified petroleum gas (LPG). For diesel engines, air toxics may also be differentiated by large and small engine horsepower classifications (described in greater detail in Section 3.1).

1.1 Air Toxics in MOVES2014a

The air toxics included in MOVES2014a are classified into four categories:

1) Volatile Organic Compounds (VOC): EPA defines VOC as any compound of carbon--excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate--which participates in atmospheric photochemical reactions, except those designated by EPA as having negligible photochemical reactivity.[1]
2) Polycyclic aromatic hydrocarbons (PAHs): This category is defined as hydrocarbons containing fused aromatic rings. These compounds can be measured in the gaseous phase, particulate phase, or both, depending on properties of the compound, particle characteristics and conditions in the exhaust stream or the atmosphere.
3) Dioxins and furans: This category includes polychlorinated organic compounds which are persistent in the environment and considered bioaccumulative in aquatic and terrestrial food chains.
4) Metals: This category includes metals or metal-containing compounds in elemental, gaseous and particulate phases.

Specific compounds in each category are listed in Table 1 through Table 4 and are identical to the compounds modeled for highway vehicles. Note that each compound is identified by its

[A] Prior to MOVES, the mobile source inventory model used was the National Mobile Inventory Model (NMIM). NMIM incorporated onroad and the NONROAD model to calculate emission inventories.

"pollutantID" in the MOVES database. With the exception of the metal species in Table 4, each compound is also identified by its Chemical Abstracts Service Registry number (CAS number).

Table 1. Hydrocarbons and volatile organic compounds included in MOVES2014a

Pollutant	pollutantID	CAS Number
Benzene	20	71-43-2
Ethanol	21	64-17-5
1,3-Butadiene	24	106-99-0
Formaldehyde	25	50-00-0
Acetaldehyde	26	75-07-0
Acrolein	27	107-02-8
Methyl-Tertiary-Butyl Ether (MTBE)	22	1634-04-4
2,2,4-Trimethylpentane	40	540-84-1
Ethyl Benzene	41	100-41-4
Hexane	42	110-54-3
Propionaldehyde	43	123-38-6
Styrene	44	100-42-5
Toluene	45	108-88-3
Xylene(s)[1]	46	1330-20-7
[1] This species represents the sum of emissions from three isomers of xylene, i.e., *ortho*-, *meta*-, and *para*-xylene.		

Table 2. Polycyclic aromatic hydrocarbons included in MOVES2014a

Pollutant	pollutantID		CAS Number
	(gaseous phase)	(particulate phase)	
Acenaphthene	170	70	83-32-9
Acenaphthylene	171	71	208-96-8
Anthracene	172	72	120-12-7
Benz(*a*)anthracene	173	73	56-55-3
Benzo(*a*)pyrene	174	74	50-32-8
Benzo(*b*)fluoranthene	175	75	205-99-2
Benzo(*g,h,i*)perylene	176	76	191-24-2
Benzo(*k*)fluoranthene	177	77	207-08-9
Chrysene	178	78	218-01-9
Dibenzo(*a,h*)anthracene	168	68	53-70-3
Fluoranthene	169	69	206-44-0
Fluorene	181	81	86-73-7
Indeno(1,2,3,*c,d*)pyrene	182	82	193-39-5
Naphthalene	185	23	91-20-3
Phenanthrene	183	83	85-01-8
Pyrene	184	84	129-00-0

Table 3. Dioxins and furans included in MOVES2014a

Pollutant	pollutantID	CAS Number
2,3,7,8-Tetrachlorodibenzo-p-Dioxin	142	1746-01-6
1,2,3,7,8-Pentachlorodibenzo-p-Dioxin	135	40321-76-4
1,2,3,4,7,8-Hexachlorodibenzo-p-Dioxin	134	39227-28-6
1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin	141	57653-85-7
1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin	130	19408-74-3
1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin	132	35822-46-9
Octachlorodibenzo-p-dioxin	131	3268-87-9
2,3,7,8-Tetrachlorodibenzofuran	136	51207-31-9
1,2,3,4,6,7,8-Heptachlorodibenzofuran	144	67562-39-4
1,2,3,4,7,8,9-Heptachlorodibenzofuran	137	55673-89-7
1,2,3,4,7,8-Hexachlorodibenzofuran	145	70648-26-9
1,2,3,6,7,8-Hexachlorodibenzofuran	140	57117-44-9
1,2,3,7,8,9-Hexachlorodibenzofuran	146	72918-21-9
1,2,3,7,8-Pentachlorodibenzofuran	139	57117-41-6
2,3,4,6,7,8-Hexachlorodibenzofuran	143	60851-34-5
2,3,4,7,8-Pentachlorodibenzofuran	138	57117-31-4
Octachlorodibenzofuran	133	39001-02-0

Table 4. Metals included in MOVES2014a

Pollutant	pollutantID	CAS Number
Mercury (elemental gaseous)	60	7439-97-6
Mercury (divalent gaseous)	61	7439-97-6
Mercury (particulate)	62	7439-97-6
Arsenic compounds	63	7440-38-2 (metal)
Chromium (Cr6+)	65	18540-29-9
Manganese compounds	66	7439-96-5 (metal)
Nickel compounds	67	7440-02-0 (metal)

1.2 Speciation

In addition to estimating emissions of pollutants that are discrete chemical compounds, such as carbon monoxide (CO) and sulfur dioxide (SO_2), MOVES2014a produces emission rates for aggregates of individual chemical compounds, including total hydrocarbons (THC), volatile organic compounds (VOC), total organic gases (TOG) and particulate matter (PM). These pollutants are operationally defined, meaning that their definition depends on the measurement technique(s) selected. For example, THC is defined as the hydrocarbons measured by a flame ionization detector (FID). THC measurements do not respond fully to carbon-oxygen bonds in oxygenated compounds, such as aldehydes, alcohols, and ketones. TOG is intended to include all organic gases, including oxygenated compounds, and is measured using gas and liquid chromatography methods. Thus, differences in measurement methods need to be considered

when comparing THC to TOG emission measurements. Similarly, particulate matter is operationally defined as the measured mass collected on a filter using EPA-defined sampling filter media, conditions, and practices. $PM_{2.5}$ refers to particulate matter emissions collected downstream of a cyclone that removes the particles with aerodynamic diameter greater than 2.5 microns, while PM_{10} refers to particulate matter emissions with aerodynamic diameter less than 10 microns.

Previous versions of MOVES produced highway vehicle emission estimates for a subset of species that contribute to TOG and $PM_{2.5}$. These include important organic gaseous toxics (e.g., formaldehyde and benzene), and toxic particle-phase elements (e.g., nickel and manganese). These also include semi-volatile organic compounds, such as 15 individual polycyclic aromatic hydrocarbons (e.g., benzo(*g*,*hi*,*i*)perylene) that can exist in both the gaseous and particle phases under different measurement conditions.

However, prior to MOVES2014, the individual species produced by MOVES had to be processed outside MOVES by emission pre-processors into a form suitable for use in air-quality modeling. The process of apportioning aggregate TOG and $PM_{2.5}$ into sets of separate components is called "speciation." MOVES2014 incorporated the process of TOG and $PM_{2.5}$ speciation for highway vehicles, and can produce the TOG and $PM_{2.5}$ species needed by air quality models. The reasoning for bringing the speciation capability inside MOVES is further described elsewhere.[2]

In MOVES2014a, toxics are estimated from the nonroad portion of the model, similar to the highway sources. However, TOG speciation, including the calculation of chemical mechanism species, and PM2.5 speciation from nonroad sources continue to be conducted in SMOKE with the use of MOVES2014a. However, nonroad emissions from MOVES2014a include a higher level of detail than in NONROAD2008, and can be distinguished by engine type, engine technology, engine size, fuel and fuel sub-type, and emission processes. These factors are the factors used to categorize distinctions in TOG and PM speciation profiles. By outputting the emissions by these factors, the speciation of nonroad emissions can occur in SMOKE without any loss of information.

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1.3 Methods

We conducted a literature review of air toxics from nonroad engines and concluded that the best available data sets for nonroad engines were from two test programs conducted by Southwest Research Institute (SwRI), under contracts from EPA. Exhaust emissions data from these programs were used to create VOC speciation profiles and gaseous toxic emission fractions for nonroad spark-ignition (SI) engines[3] and nonroad compression ignition (CI) engines.[4,5] The test programs and derivation of these speciation profiles are explained further in Appendix A and in the literature.[6] Data from the CI test programs were also used to develop PAH emission fractions. Data from the SI engine test program provided the basis for profiles of uncontrolled 2-stroke and 4-stroke engines operating on gasoline (E0) and gasoline containing 10% ethanol by volume (E10). Data from the CI engine test programs provided the basis for profiles of pre-Tier 1, Tier 1, and Tier 2 engines at various power levels.

Where data on nonroad emissions were absent, nonroad emission factors were derived from onroad vehicles. Onroad emission factors surrogates were used for nonroad gasoline engine emissions of PAHs, metals, and dioxins/furans; diesel engine emissions of VOCs for Tier 4 ≥56kW engines, PAHs for Tier 4 ≥56kW engines, metals, and dioxins/furans; and all air toxics from CNG and LPG engines. For detailed information on the data and derivation of emission factors for onroad vehicles, please refer to the peer-reviewed EPA report entitled **Air Toxic Emissions from Onroad Vehicles in MOVES2014** (referred to in this document as the "onroad air toxics report").[7]

It is important to note that emissions factors for nonroad engines and equipment are based on composites of running and cold start emissions and currently there are not separate emission factors for idling, start, or hot-stabilized running emissions. It should also be mentioned that toxic fractions are mass-based (as opposed to using molar-ratios) and inputs used to estimate emissions of toxics do not vary by temperature.

2.0 Gasoline Exhaust

2.1 Organic Gas Aggregations and Air Toxic Emission Factors

In the absence of data, a single spark-ignition test program3 (further described in Appendix A) was used to develop exhaust emission factors according to engine type (2-stroke or 4-stroke) and fuel subtype (E0 or E10). The choice of 2-stroke or 4-stroke technology and the choice of gasoline ethanol level are generally the most important factors influencing nonroad gasoline engine speciated emissions and thus all nonroad gasoline engines were assigned volatile organic compound (VOC) profiles according to stroke and fuel subtype. The presence of a three-way catalyst also influences emissions; however, as described in Appendix A, the test engines were not equipped with a catalyst.

In the MOVES model, individual VOC fractions are multiplied by total VOC emissions to obtain emission factors. Total VOC was derived from FID-measured non-methane hydrocarbons (NMHC) by first calculating non-methane organic gases (NMOG) according to 40 CFR §1066.635 (Equation 1):[8]

Equation 1

$$m_{NMOG} = m_{NMHC} + m_{oxygenates} - \rho_{NMHC} \cdot \sum_{i=1}^{N} \frac{m_{oxygenate_i}}{\rho_{oxygenate_i}} \cdot FID_{RF_i}$$

Where:
m_{NMHC} = the mass of NMHC and all oxygenated hydrocarbons in the exhaust
m_{NMOG} = the mass of NMOG in the exhaust
$m_{oxygenates}$ = the mass of formaldehyde and acetaldehyde
ρ_{NMHC} = the effective C_1-equivalent density of NMHC, calculated using a C:H ratio of 1:2.64
$m_{oxygenate\ i}$ = the mass of oxygenated species *i* in the exhaust as indicated in Table 19
$\rho_{oxygenate\ i}$ = the C_1-equivalent density of oxygenated species *i*

From NMOG, total organic gases (TOG) can be obtained by the addition of methane. Per the definition of VOCs discussed in the introduction, VOCs are obtained from NMOG by the removal of ethane and acetone.

Equation 2

$$VOC = NMOG - ethane - acetone$$

Table 5 lists aggregate species (or groups of chemical compounds defined operationally or for modeling purposes) including THC, NMHC, NMOG, TOG and VOC, and also includes ratios used to derive NMOG, VOC and methane from THC and NMHC. NMHC was derived from the THC and methane emissions, NMOG was derived from Equation 1, VOC from Equation 2, and TOG as the sum of NMOG + methane. NMOG/NMHC and VOC/NMHC factors are derived from these values are also presented.

Table 5. Organic gas aggregations estimated from THC for nonroad gasoline engines in MOVES 2014a

Engine Technology	**2-stroke**	**2-stroke**	**4-stroke**	**4-stroke**
Fuel sub-type	**E0**	**E10**	**E0**	**E10**
Mass units[a]	***mg/mi***	***mg/mi***	***mg/hp-hr***	***mg/hp-hr***
THC	36235	31510	6667	5855
NMHC	35491	30875	5622	4981
NMOG	35687	32733	5774	5232
TOG	36432	33368	6819	6107
VOC	35586	32631	5692	5156
CH_4	744	635	1045	874
NMOG/NMHC	1.006	1.060	1.027	1.051
CH_4/THC	0.021	0.020	0.157	0.149
VOC/NMHC	1.003	1.057	1.012	1.035

[a] 2-stroke engines were measured on a transient test cycle and 4-stroke engines were measured on a steady-state cycle, per Appendix A

Emission factors for individual VOC are reported as the fraction of the individual species divided by total VOCs (Table 6). The remaining VOC species have been integrated into the term NONHAPTOG which is listed at the bottom of Table 6.

Table 6. Nonroad gasoline toxic fractions for VOC included in MOVES2014a

Pollutant	E0 4 stroke	E0 2 stroke	E10 4 stroke	E10 2 stroke
1,3-Butadiene	0.01280	0.00214	0.01240	0.00272
2,2,4-Trimethylpentane	0.04610	0.08110	0.05720	0.13000
Acetaldehyde	0.00425	0.00103	0.00897	0.00336
Acrolein	0.00037	0.00031	0.00045	0.00044
Benzene	0.06940	0.01390	0.04590	0.01260
Ethanol	0.00172	0.00058	0.03030	0.07810
Ethyl Benzene	0.02200	0.03440	0.01670	0.02230
Formaldehyde	0.01980	0.00368	0.01760	0.00498
Hexane	0.00233	0.00772	0.00520	0.00715
m-& p-Xylene	0.04400	0.06440	0.05460	0.05390
Methyl t-butyl ether (MTBE)	0.00000	0.00000	0.00000	0.00000
o-Xylene	0.01460	0.02320	0.01530	0.01860
Propionaldehyde	0.00049	0.00051	0.00041	0.00052
Styrene	0.00976	0.00223	0.00715	0.00177
Toluene	0.08640	0.08640	0.07770	0.07770
NONHAPTOG	0.66600	0.67800	0.65000	0.58600

2.2 Polycyclic Aromatic Hydrocarbons

Emissions of PAH in the gaseous and particulate phases were estimated as fractions of total VOC and $PM_{2.5}$, respectively (Equations 3 and 4). PAH emission factors for nonroad gasoline engines were adapted from onroad gasoline engine data (described in section 2.2.1 of the on-road air toxics report), due to unavailability of data for nonroad engines. However, since the nonroad portion of MOVES2014a does not produce speciated $PM_{2.5}$ measurements (in particular, it does not estimate the carbon fraction of $PM_{2.5}$), nonroad PAH emissions are estimated from total $PM_{2.5}$ emissions as opposed to the $OC_{2.5}$ used for onroad emissions. The onroad gasoline PAH emission factor is applied to both 2-stroke and 4-stroke gasoline engines and both E0 and E10 fuel subtypes.

Equation 3

$$PAH\ gaseous\ emission\ factor = \frac{PAH_i}{VOC_{total}} \times Gaseous\ Fraction_i$$

Equation 4

$$PAH\ particulate\ emission\ factor = \frac{PAH_i}{PM_{2.5}} \times Particulate\ Fraction_i$$

Table 7. Toxic fractions for PAH compounds in gaseous and particulate phases for nonroad gasoline engines

Species	Gaseous Phase (PAH/VOC)	Particulate Phase (PAH/$PM_{2.5}$)
Naphthalene	2.07E-03	6.38E-05
Acenaphthylene	1.81E-04	2.09E-05
Acenaphthene	3.99E-05	0.0
Fluorene	8.08E-05	0.0
Anthracene	3.35E-05	2.21E-05
Phenanthrene	2.14E-04	7.80E-05
Fluoranthene	5.60E-05	7.81E-05
Pyrene	6.40E-05	8.47E-05
Benz(a)anthracene	5.40E-06	2.03E-04
Chrysene	6.05E-06	1.72E-04
Benzo(a)pyrene	2.94E-07	5.09E-04
Benzo(b)fluoranthene	4.01E-06	2.48E-04
Benzo(k)fluoranthene	4.01E-06	2.48E-04
Benzo(g,h,i)perylene	0.0	1.38E-03
Indeno(1,2,3,c,d)pyrene	0.0	5.17E-04
Dibenzo(a,h)anthracene	0.0	1.19E-05

2.3 Metals

Emission factors for chromium 6, manganese, nickel, elemental gas-phase mercury (Hg), reactive gas-phase Hg, particulate Hg, and arsenic were developed based on existing onroad gasoline emission factors in MOVES2014 (Table 51 of the onroad air toxics report) due to the lack of nonroad emissions tests data for these compounds. Onroad emission factors from MOVES2014 were used as surrogates and converted from grams-per-mile to grams-per-gallon using study-specific, miles per gallon (mpg) fuel economy estimates.

Chromium 6 was estimated using data collected at U.S. EPA's National Vehicle Emissions Laboratory and analyzed at the Wisconsin State Laboratory of Hygiene at the University of Wisconsin-Madison. These data were collected on a single vehicle, a 2008 Chevrolet Impala flexible-fuel vehicle. They are the only available data with direct measurement of hexavalent chromium from a highway vehicle, gasoline or diesel. Development of a gasoline vehicle emission rate from these data is detailed in Appendix A of the onroad air toxics report. Eighteen percent of chromium was assumed to be hexavalent, based on combustion data from stationary combustion turbines burning diesel fuel.[9] To obtain the chromium 6 nonroad gasoline emission factor, the onroad emission factor was converted to grams-per-gallon by using the Impala's fuel economy estimate of 18 miles per gallon.

Nonroad gasoline vehicle emission factors for mercury (all phases) were obtained from the onroad air toxics report, Appendix B. Nonroad grams-per-gallon emission factors were calculated from the onroad factors using a fuel economy estimate of 17 miles per gallon.

Emission rates for manganese and nickel were developed from 99 vehicles sampled for chemical composition in the Kansas City test program.[10] For manganese and nickel, the mean rates were calculated as weighted averages of metal measured on Bag 2 of the LA92 test cycle. A fuel economy estimate of 20.43 mpg was calculated from vehicles in the Kansas City test program.

The emission rate for arsenic is from a Health Effects Institute research report.[11] In the absence of a study-specific fuel economy estimate for the vehicles used in the study, the 2000 fuel economy standard for gasoline vehicles (27.5 mpg) was used to reflect the fleet average fuel economy at the time when the majority of data were collected.

A single factor for each metal is applied to all nonroad gasoline engines and fuel sub-types (E0 and E10).

Table 8. Metal emission factors for nonroad gasoline engines

Pollutant	Emission Factor (g/gal)
Chromium 6	2.20E-07
Manganese	2.72E-05
Nickel	3.06E-05
Elemental Gas-Phase Hg	1.80E-06
Reactive Gas-Phase Hg	1.70E-07
Particulate Hg	6.90E-09
Arsenic	6.33E-05

2.4 Dioxins and Furans

Emission factors for 17 dioxins and furans were developed (Table 9) based on onroad emission factors (detailed in section 2.4 of the onroad air toxics report) because of a lack of available data for nonroad engines. Onroad emission rates from MOVES2014 were obtained from a tunnel study[12] and used in EPA's dioxin assessment.[13] These emission rates were converted from TEQ (Toxicity Equivalence)[B] grams-per-mile to TEQ grams-per-gallon using a fuel economy of 23.5 miles-per-gallon from the tunnel study. Due to a lack of dioxin and furan test data differentiating 2-stroke and 4-stroke engines, the dioxin/furan emission factors in Table 9 will be applied to all nonroad gasoline engines. Each dioxin and furan is also applied across all fuel sub-types.

[B] Toxicity Equivalence. The various dioxin/furan congeners are expressed as TEQs of the most toxic congener (2,3,7,8 TCDD). Further explanation can be found in section 2.4 of the on-road air toxics report.

Table 9. Dioxin and furan emission factors for nonroad gasoline engines

Pollutant	Highway Vehicle Emission Rate TEQ (g/mi)	Emission Factor TEQ (g/gal)
2,3,7,8-Tetrachlorodibenzo-*p*-Dioxin (TCDD)	8.27E-10	1.95E-08
1,2,3,7,8-Pentachlorodibenzo-*p*-Dioxin	3.70E-10	8.70E-09
1,2,3,4,7,8-Hexachlorodibenzo-p-Dioxin	3.87E-11	9.10E-10
1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin	7.92E-11	1.86E-09
1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin	4.93E-11	1.16E-09
1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin	5.95E-11	1.40E-09
Octachlorodibenzo-p-dioxin	1.41E-11	3.32E-10
2,3,7,8-Tetrachlorodibenzofuran	2.76E-10	6.49E-09
1,2,3,7,8-Pentachlorodibenzofuran	3.96E-11	9.31E-10
2,3,4,7,8-Pentachlorodibenzofuran	2.90E-10	6.82E-09
1,2,3,4,7,8-Hexachlorodibenzofuran	1.09E-10	2.56E-09
1,2,3,6,7,8-Hexachlorodibenzofuran	1.16E-10	2.73E-09
1,2,3,7,8,9-Hexachlorodibenzofuran	3.17E-11	7.46E-10
2,3,4,6,7,8-Hexachlorodibenzofuran	1.36E-10	3.20E-09
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1.21E-10	2.85E-09
1,2,3,4,7,8,9-Heptachlorodibenzofuran	3.87E-12	9.10E-11
Octachlorodibenzofuran	4.11E-12	9.67E-11

3.0 Diesel Exhaust

3.1 Organic Gas Aggregations and Air Toxic Emission Factors

Diesel engines were assigned VOC exhaust emission factors according to engine control technology, as determined by the engine certification tier or phase, and engine size. Pre-Tier 1, Tier 1, and Tier 2 diesel engine VOC profiles were developed from EPA's nonroad CI test programs.[4,5] In the absence of data, we applied the VOC profile developed for Tier 2 engines to Tier 3 engines. The same VOC profiles are being applied across all engine sizes within each of the Tier 3-and-earlier technology groups.

The stringency of the nonroad diesel Tier 4 emission standards varies considerably depending on engine size. The NMHC standards are relatively unchanged for engines smaller than 56 kW with Tier 4, so we have continued to apply the developed Tier 2 VOC emission profile to all Tier 4 engines smaller than 56 kW.

For engines greater than 56 kW, the emission standards for NMHC and NOx standards are significantly reduced with Tier 4 vehicles. These standards have forced different configurations

of emission control technologies, utilizing advanced technology such as diesel oxidation catalysts, diesel particulate filters, selective reduction catalysts, and ammonia slip catalysts.

The onroad 2007 heavy-duty diesel profiles are based on heavy-duty diesel onroad engines equipped with diesel oxidation catalysts and diesel particulate filters. Because the onroad 2007 heavy-duty diesel profile is based on advanced emission control technology, it is assumed to better represent large Tier 4 nonroad engines which must meet tighter emission standards. For Tier 4 diesel engines ≥56 kW, we applied the speciated emissions factors derived from Phase 1 of the Advanced Collaborative Emissions Study (ACES), directed by the Health Effects Institute and Coordinating Research Council, with participation from a range of government and private-sector sponsors.[14]

Ratios for diesel engines were calculated using THC measurements, similar to the way we generated gasoline VOC ratios (Section 2.1); this information is displayed in Table 10. NMHC was calculated using Equation 1 but the effective C_1-equivalent density of NMHC was calculated from a diesel #2 C:H ratio of 1:1.8. VOC and methane emission rates used to develop emission factors for all diesel engines except Tier 4 ≥56kW engines were from the final TOG speciation profiles listed in Appendix A of this document. Methane for Tier 4 ≥56kW diesel engines is based on federal test procedure (FTP) data from advanced onroad heavy-duty vehicles.[15] The derivation of NMOG/NMHC and VOC/NMHC rates for Tier 4 ≥56kW diesel engines are taken from the onroad model year group of 2007-2050 as documented in the MOVES2014 Speciation of TOG and PM Emissions report.2

VOC profiles were created by subtracting the values for methane, ethane, and acetone from TOG profiles in Appendix A. Emission factors are reported in fractions of individual species over total VOCs (Table 11). The remaining VOC species have been integrated into the term NONHAPTOG which is listed at the bottom of Table 11.

Table 10. Methane and organic gas ratios estimated from THC for nonroad diesel engines in MOVES 2014a

Engine technology	**Pre-Tier 1**	**Tier 1**	**Tiers 2 & 3**	**Tier 4**	**Tier 4**
Fuel type	**Diesel**	**Diesel**	**Diesel**	**Diesel**	**Diesel**
Engine power	**All**	**All**	**All**	**<56 kW**	**≥56 kW**
CH_4 [a]	3.567	4.722	7.960	7.960	0.0039
NMOG/NMHC	1.067	1.116	1.233	1.233	1.3431
CH_4/THC	0.005	0.022	0.098	0.098	
VOC/NMHC	1.062	1.110	1.233	1.233	1.3058

[a] The units for methane emission rates are all mg/hp-hr except for Tier 4 ≥56kW engines which are in g/mile

Table 11. Toxic fractions of VOC for nonroad diesel vehicles according to engine tier control

Pollutant	Toxic fraction				
	Pre-Tier 1	Tier 1	Tiers 2 & 3	Tier 4 (<56 kW)	Tier 4 (≥56 kW)
1,3-BUTADIENE	0.00186	0.00186	0.00186	0.00186	0.00080
2,2,4-TRIMETHYLPENTANE	0.00807	0.00712	0.00783	0.00783	0.00782
ACETALDEHYDE	0.0746	0.0783	0.104	0.104	0.06934
ACROLEIN	0.0302	0.0160	0.0187	0.0187	0.00999
BENZENE	0.0196	0.0225	0.0541	0.0541	0.01291
ETHYLBENZENE	0.00944	0.00384	0.00438	0.00438	0.00627
FORMALDEHYDE	0.207	0.223	0.292	0.292	0.21744
HEXANE	0.00230	0.00279	0.000	0.000	0.00541
XYLENES	0.02256	0.01644	0.0116	0.0116	0.0380
PROPIONALDEHYDE	0.0141	0.0386	0.0220	0.0220	0.00314
STYRENE	0.000	0.000	0.000	0.000	0.000
TOLUENE	0.0122	0.0215	0.0378	0.0378	0.02999
NONHAPTOG	0.598	0.568	0.446	0.446	0.59889

3.2 Polycyclic Aromatic Hydrocarbons

As was done for gasoline engines, PAH mass emissions from diesel engines were apportioned into gaseous and particulate phases, using a single set of allocation factors for all temperature conditions. The partitioning factors for diesel PAHs are listed in Table 58 of the onroad air toxics report. It should be noted that the data used represent partitioning is the sampled diluted exhaust, which is not representative of partitioning in the atmosphere.

Emissions of PAH in the gaseous and particulate phases were estimated as fractions of total VOC and $PM_{2.5}$, respectively (Equations 3 and 4). Toxic fractions were determined according to the same emission standard and horsepower distinctions discussed in the prior section. Toxic fractions for Pre-Tier 1, Tier 1, Tier 2, Tier 3, and Tier 4 <56kW were calculated using the composite mass results from the EPA nonroad compression-ignition transient test program described in Appendix A. In the absence of PAH data on nonroad engines with advanced controls (Tier 4 engines ≥56kW), we relied on onroad engine speciated emissions data from the ACES study.[14]

Particle phase PAHs were taken from the same data on onroad conventional heavy duty diesel engines (hot stabilized running, profile 8995) detailed in the onroad air toxics report. However, while onroad PAHs are calculated from $OC_{2.5,}$ MOVES does not estimate organic carbon for nonroad equipment. Thus, MOVES calculates nonroad PAH emissions as a fraction of total $PM_{2.5}$.

Gaseous results and particulate results were averaged separately according to the categories identified in Table 3-2 of Appendix A. The resulting PAH EFs are displayed in Table 12. As explained above, for Tier 4 engines ≥56kW, we used data from onroad engines with similar

control technologies, such as diesel particulate filters. These onroad results were summarized in Table 63 of the onroad air toxics report.

Table 12. PAH emission factors for nonroad diesel engines

	Pre-Tier 1		Tier 1		Tier 2, Tier 3, & Tier 4 <56kW		Tier 4 ≥56kW	
Pollutant	***Gaseous***	***Particle***	***Gaseous***	***Particle***	***Gaseous***	***Particle***	***Gaseous***	***Particle***
Benz(a)anthracene	2.56E-06	4.51E-06	3.22E-06	3.24E-06	7.81E-06	7.76E-06	3.00E-07	8.00E-07
Benzo(a)pyrene	0.0	2.14E-06	0.0	2.13E-06	0.0	6.67E-06	0.0	3.30E-06
Benzo(b)fluoranthene	0.0	2.47E-06	0.0	2.60E-06	0.0	1.07E-05	0.0	1.40E-06
Benzo(k)fluoranthene	0.0	2.09E-06	0.0	2.03E-06	0.0	8.10E-06	0.0	1.40E-06
Chrysene	1.96E-06	7.89E-06	3.85E-06	6.26E-06	7.68E-06	1.31E-05	5.00E-07	2.50E-06
Dibenz(a,h)anthracene	0.0	1.89E-06	0.0	9.64E-07	0.0	9.52E-07	0.0	1.00E-06
Indeno(1,2,3-cd)pyrene	0.0	2.02E-06	0.0	1.53E-06	0.0	6.72E-06	0.0	5.00E-07
Benzo(ghi)perylene	6.20E-07	1.80E-06	1.22E-06	1.62E-06	5.70E-06	7.55E-06	2.00E-07	2.00E-07
Acenapthene	9.59E-04	0.0	3.79E-04	0.0	6.06E-04	0.0	5.26E-05	0.0
Acenapthylene	4.64E-04	0.0	4.95E-04	0.0	1.24E-03	0.0	8.53E-05	0.0
Anthracene	8.74E-05	6.63E-05	4.63E-05	1.95E-05	8.81E-05	2.90E-05	3.04E-05	2.65E-05
Fluoranthene	2.27E-05	2.07E-05	5.22E-05	1.78E-05	1.45E-04	5.59E-05	4.57E-05	4.87E-05
Fluorene	1.15E-03	2.71E-04	5.00E-04	5.75E-05	7.90E-04	7.98E-05	1.96E-04	5.38E-05
Napthalene	3.18E-03	0.0	2.73E-03	0.0	4.64E-03	0.0	1.63E-02	0.0
Phenanthrene	1.56E-03	6.79E-04	1.03E-03	2.03E-04	1.28E-03	2.37E-04	8.51E-04	4.29E-04
Pyrene	7.51E-05	8.28E-05	6.65E-05	3.20E-05	1.30E-04	6.15E-05	3.79E-05	4.67E-05

3.3 Metals

Emission factors for chromium 6 (also seen as chromium-6, chromium VI, Cr6+ and CrVI), manganese, nickel, elemental gas-phase mercury (Hg), reactive gas-phase Hg, particulate Hg, and arsenic were developed based on existing onroad emission factors in MOVES2014 (Tables 60 and 64 of the onroad air toxics report) due to the lack of nonroad emissions test data for these compounds. Onroad emission factors were converted from grams-per-mile to grams-per-gallon using study-specific, miles-per-gallon (mpg) fuel economy estimates. Studies used in developing onroad emission factors and study-specific fuel economy estimates are outlined in the notes of Table 13. Study-specific fuel economy estimates were unavailable for metals on some engine types, therefore average fuel economies were used as indicated in the notes of Table 13. Where there was information to do so, diesel engine emission factors were determined by engine tier and power (as described in Section 3.1).

Chromium 6 emissions factors for nonroad diesel engines were developed from an onroad gasoline engine. The chromium 6 emission factor for Tier 0 – Tier 3 and Tier 4 <56kW diesel engines was obtained by multiplying the highway gasoline vehicle emission rate (documented in Appendix A of the onroad air toxics report) by the ratio of total chromium in diesel exhaust[16] to that in gasoline exhaust.[17] For Tier 4 engines ≥ 56kW, the chromium 6 emission rate was

obtained by multiplying the gasoline vehicle emission rate by the ratio of total chromium from diesel and gasoline engines. The total chromium estimates came from the ACES[14] and Kansas City test programs, respectively.

Mercury (all phases) emission factors were calculated from two onroad heavy-duty diesel vehicles as documented in Appendix B of the onroad air toxics report.

Emission factors for arsenic were developed from onroad data reported in tunnel studies.[11] The fuel average economy for these vehicles was not reported, so, because most of the data was collected in 2000, the model-year-2000 average heavy-duty diesel fuel economy of 7 miles-per-gallon was used.

Emission factors for manganese and nickel were developed from the CRC E-55/59[18] test program for Tier 0 – Tier 3 and Tier 4 <56kW diesel engines. To convert the grams-per-mile highway vehicle emission rate to grams-per-gallon, an average (4.3 g/gal) was computed from the UDDS mile/gallon values from Tables 26 and 27 of the report. For Tier 4 ≥56 kW nonroad diesel engines, emission factors were developed from ACES.[7,14] A study-specific fuel economy of 6 mile-per-gallon was used from page 31 of the ACES report.[14]

Table 13. Metal emission factors for nonroad diesel engines

Engine Tier & Power	Pollutant	Emission Factor (g/gal)
Tier 0 – Tier 3, Tier 4 (<56 kW)	Chromium 6	3.70E-07
	Manganese	3.46E-05
	Nickel	6.05E-05
	Elemental Gas-Phase Hg	1.20E-07
	Reactive Gas-Phase Hg	6.20E-08
	Particulate Hg	3.20E-08
	Arsenic	1.61E-05
Tier 4 (≥56 kW)	Chromium 6	1.00E-07
	Manganese	3.30E-06
	Nickel	3.90E-06
	Elemental Gas-Phase Hg	1.20E-07
	Reactive Gas-Phase Hg	6.20E-08
	Particulate Hg	3.20E-08
	Arsenic	1.61E-05

3.4 Dioxins and Furans

Emission factors for 17 dioxins and furans were developed and based on onroad emission factors because of a lack of available data for nonroad engines. Onroad emission rates from MOVES2014 were used as surrogates and converted from TEQ grams-per-mile to TEQ grams-per-gallon (Table 14).

To represent emissions of dioxins and furans from onroad pre-2007 (pre-Tier 4) heavy-duty diesel engines, emissions rates for 17 congeners were calculated from the results of an EPA diesel dioxin/furan study of legacy engines.[19] The data used to calculate the emission rates for

Tier 4 engines were obtained from the EPA diesel dioxin study of onroad 2007-and-later engines.[20] More information on the development of the onroad diesel emission rates and the studies used can be found in Sections 3.4 and 4.4 of the onroad air toxics report.

Dioxins and furans are formed in the exhaust after combustion and may not be affected by after-treatment control technologies in the same way as other air toxics. Thus we have grouped the emission factors for these pollutants differently. In particular, we expect less sophisticated engine combustion technologies on Tier 0, Tier 1, Tier 2 and the smaller Tier 3 and Tier 4 diesel engines, and thus higher dioxin and furan emissions on a per gallon basis. The rated-power of 56 kW (75hp) was used as the dividing line between smaller and larger engines because NMHC-specific Tier 4 standards only apply to 56 kW-and-larger engines. Tier 3 ≥ 56kW engines are considered to have similar dioxin/furan emissions as Tier 4 engines ≥ 56kW based on observations in Laroo et al. 2011. For all Tier 0, Tier 1, Tier 2 and the Tier 3 and Tier 4 engines diesel engines less than 56 kW we used an average of emission factors from three legacy engines.[19] For Tier 3 and Tier 4 diesel engines ≥ 56kW, we used the emission factor from a modern 2010 on-highway engine.[20]

Table 14. Dioxin and furan emission factors for nonroad diesel engines

			Emission Factor TEQ (g/gal)	
Pollutant ID	**CAS Number**	**Pollutant**	**Tier 0 – Tier 2 (all hp categories), Tier 3 and Tier 4 (<56 kW)[1]**	**Diesel ≥ 56 kW Tiers 3 and 4 [2]**
142	17466016	2,3,7,8-Tetrachlorodibenzo-*p*-Dioxin (TCDD)	1.21E-11	ND*
135	40321764	1,2,3,7,8-Pentachlorodibenzo-*p*-Dioxin	ND	ND
134	39227286	1,2,3,4,7,8-Hexachlorodibenzo-p-Dioxin	ND	ND
141	57653857	1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin	2.81E-12	ND
130	19408743	1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin	1.30E-11	ND
132	35822469	1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin	7.59E-11	1.90E-11
131	3268879	Octachlorodibenzo-p-dioxin	2.93E-10	1.27E-10
136	51207319	2,3,7,8-Tetrachlorodibenzofuran	1.18E-10	9.24E-13
139	57117416	1,2,3,7,8-Pentachlorodibenzofuran	2.52E-11	1.95E-12
138	57117314	2,3,4,7,8-Pentachlorodibenzofuran	4.05E-11	5.89E-12
145	70648269	1,2,3,4,7,8-Hexachlorodibenzofuran	2.19E-11	4.00E-12
140	57117449	1,2,3,6,7,8-Hexachlorodibenzofuran	1.16E-11	4.41E-12
146	60851345	1,2,3,7,8,9-Hexachlorodibenzofuran	8.26E-12	3.27E-12
143	72918219	2,3,4,6,7,8-Hexachlorodibenzofuran	ND	ND
144	67562394	1,2,3,4,6,7,8-Heptachlorodibenzofuran	3.93E-11	1.80E-11
137	55673897	1,2,3,4,7,8,9-Heptachlorodibenzofuran	ND	1.06E-12
133	39001020	Octachlorodibenzofuran	3.37E-11	3.15E-11

*ND = non-detect, fractions set to zero

1. Used an average of the pre-2007 legacy engines, converted pg/L to g/gal

2. Used the emission factors from a modern 2010 engine, converted pg/L to g/gal

4.0 Compressed Natural Gas Exhaust

4.1 Organic Gas Aggregations and Air Toxic Emission Factors

In absence of data on nonroad engines, VOC emission factors are borrowed from onroad CNG transit buses (Table 66 of the onroad air toxics report). Without additional test data, a conservative approach to emissions estimates was used and the toxic fractions were based on uncontrolled (pre-2002) transit buses (Table 15).

Table 15. Toxic fractions of VOC for nonroad CNG engines

Pollutant	Toxic fraction
1,3 Butadiene	0.000234
Benzene	0.00135
Toluene	0.000691
Ethylbenzene	0.0000841
Xylenes	0.000823
Formaldehyde	0.517
Acetaldehyde	0.0305
Acrolein	0.00235
Propionaldehyde	0.0153

The derivation of the CNG NMOG/NMHC and VOC/NMHC rates is documented in the 2014 Heavy-Duty Emissions Report[21] and comes from CNG transit bus emissions with no control technologies (Table 16).[22]

Table 16. Organic gas aggregations estimated from THC for nonroad CNG engines in MOVES 2014a

Measured values (mg/mile)	
THC	8660
CH4	7670
Ethane	217
Acetone	4.67
Formaldehyde	860
Acetaldehyde	50.7
Calculated values (mg/mile)	
NMHC	990
NMOG	1881.0
VOC	1664.0
Ratios	
CH4/THC	0.886
VOC/THC	0.192
TOG/THC	1.10
NMOG/NMHC	1.90
VOC/NMHC	1.68

4.2 Polycyclic Aromatic Hydrocarbons

In the absence of data, PAH toxic fractions for CNG engines are estimated in a manner similar to PAH toxic fractions from gasoline engines. The PAH toxic fractions for CNG engines are developed from onroad CNG transit buses (Table 67 of the onroad air toxics report) and are displayed in Table 17.

Table 17. PAH emission factors for CNG engines

	Gaseous Phase (PAH/VOC)	Particulate Phase (PAH/$PM_{2.5}$)
Naphthalene	9.554E-06	1.144E-05
Acenaphthylene	4.230E-06	ND
Acenaphthene	1.243E-06	9.027E-06
Fluorene	2.986E-06	1.580E-05
Anthracene	1.164E-06	1.315E-06
Phenanthrene	8.356E-06	1.062E-05
Fluoranthene	1.936E-06	1.507E-05
Pyrene	3.743E-06	2.891E-05
Benz(a)anthracene	1.682E-07	5.155E-06
Chrysene	2.441E-07	1.083E-05
Benzo(a)pyrene	ND	ND
Benzo(b)fluoranthene	ND	ND
Benzo(k)fluoranthene	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND
Benzo(g,h,i)perylene	ND	2.633E-06
Dibenz(a,h)anthracene	ND	ND

ND = not detected, fractions set to 0.

4.3 Metals

Emission factors for chromium 6, manganese, nickel, elemental gas-phase mercury (Hg), reactive gas-phase Hg, particulate Hg, and arsenic were developed based on existing onroad CNG emission factors in MOVES2014 (Table 68 of the onroad air toxics report) due to the lack of nonroad emissions tests data for these compounds. Onroad CNG vehicle emission factors from MOVES2014 were used as surrogates and converted from grams-per-mile to grams-per-gallon. The onroad CNG emission factor was converted to a nonroad CNG emission factor by a grams-per-gallon diesel equivalent fuel economy using CNG energy rates (BTU/mile)[23] and the energy density of diesel fuel (BTU/gallon)[24] as detailed in Equation 5.

Equation 5

$$Nonroad\ CNG\ emission\ factor_{(\frac{g}{gal})} = Onroad\ CNG\ emission\ factor_{(\frac{g}{mi})} \times 131{,}225.712\ \frac{BTU}{gal} \times \frac{1}{40{,}900\frac{BTU}{mi}}$$

Table 18. Metal emission factors for nonroad CNG engines

Pollutant	Highway Vehicle Emission Rate (g/mi)	Emission Factor (g/gal)
Chromium 6	2.10E-10	6.74E-10
Manganese	1.33E-06	4.27E-06
Nickel	1.00E-08	3.21E-08
Elemental Gas-Phase Hg	1.10E-07	3.53E-07
Reactive Gas-Phase Hg	9.90E-09	3.18E-08
Particulate Hg	4.00E-10	1.28E-09
Arsenic	2.30E-06	7.38E-06

4.4 Dioxins and Furans

Emission factors for 17 dioxins and furans were developed and based on emission factors from onroad gasoline engines[12,13] (section 5.4 of the onroad air toxics report) because of a lack of available data for nonroad CNG engines (Table 19). Onroad emission rates from MOVES2014 were used as surrogates and converted from TEQ grams-per-mile to TEQ grams-per-gallon using Equation 5.

Table 19. Dioxin and furan emission factors for nonroad CNG engines

Pollutant	Highway Vehicle Emission Rate TEQ (g/mi)	Emission Factor TEQ (g/gal)
2,3,7,8-Tetrachlorodibenzo-*p*-Dioxin (TCDD)	8.27E-13	2.65E-12
1,2,3,7,8-Pentachlorodibenzo-*p*-Dioxin	3.70E-13	1.19E-12
1,2,3,4,7,8-Hexachlorodibenzo-p-Dioxin	3.87E-14	1.24E-13
1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin	7.92E-14	2.54E-13
1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin	4.93E-14	1.58E-13
1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin	5.95E-14	1.91E-13
Octachlorodibenzo-p-dioxin	1.41E-14	4.52E-14
2,3,7,8-Tetrachlorodibenzofuran	2.76E-13	8.86E-13
1,2,3,7,8-Pentachlorodibenzofuran	3.96E-14	1.27E-13
2,3,4,7,8-Pentachlorodibenzofuran	2.90E-13	9.30E-13
1,2,3,4,7,8-Hexachlorodibenzofuran	1.09E-13	3.50E-13
1,2,3,6,7,8-Hexachlorodibenzofuran	1.16E-13	3.72E-13
1,2,3,7,8,9-Hexachlorodibenzofuran	3.17E-14	1.02E-13
2,3,4,6,7,8-Hexachlorodibenzofuran	1.36E-13	4.36E-13
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1.21E-13	3.88E-13
1,2,3,4,7,8,9-Heptachlorodibenzofuran	3.87E-15	1.24E-14
Octachlorodibenzofuran	4.11E-15	1.32E-14

5.0 Liquified Petroleum Gas

5.1 Organic Gas Aggregations and Air Toxic Emission Factors

In the absence of nonroad LPG VOC data, the onroad VOC speciation profile 8860 was used to develop VOC toxic fractions for nonroad LPG engines (Table 20).[25] This profile is based on the average of three light duty onroad LPG vehicles equipped with three-way catalysts and tested in 2003.

Table 20. VOC toxic fractions for nonroad LPG engines

Pollutant	Fraction
1,3-butadiene	0.000357
Acetaldehyde	0.004466
Acetylene	0.001189
Acrolein	0.004924
Ethane	0.05549
Ethylene	0.038902
Formaldehyde	0.024523
Methane	0.176432
N-butane	0.001402
Propane	0.658555
Propylene	0.017313
Unknown	0.016448

VOC ratios were calculated from the 8860 speciation profile according to a similar method used for nonroad gasoline engines (Table 21). In absence of a THC or NMHC measurement, we calculated NMHC by reversing the equation in 40 CFR §1066.635:

Equation 6

$$m_{NMHC} = m_{NMOG} - m_{oxygenates} + \rho_{NMHC} \cdot \sum_{i=1}^{N} \frac{m_{oxygenate_i}}{\rho_{oxygenate_i}} \cdot FID_{RF_i}$$

Where:
m_{NMHC} = the mass of NMHC and all oxygenated hydrocarbons in the exhaust
m_{NMOG} = the mass of NMOG in the exhaust
$m_{oxygenates}$ = the mass of formaldehyde and acetaldehyde
ρ_{NMHC} = the effective C_1-equivalent density of NMHC, calculated using a C:H ratio of 1:2.64
$m_{oxygenate\ i}$ = the mass of oxygenated species *i* in the exhaust as indicated in Table 19
$\rho_{oxygenate\ i}$ = the C_1-equivalent density of oxygenated species *i*

Table 21. Organic gas aggregations estimated from THC for nonroad LPG engines in MOVES 2014a

NMOG/NMHC	1.035
CH_4/THC	0.181
VOC/NMHC	0.965
VOC/THC	0.790
TOG/THC	1.028

5.2 Polycyclic Aromatic Hydrocarbons

Toxic fractions for PAHs will be the same as for nonroad CNG engines (Table 17).

5.3 Metals

Emission factors for metals will be the same as for nonroad CNG engines (Table 18).

5.4 Dioxins and Furans

Emission factors for dioxins and furans will be the same as for nonroad CNG engines (Table 19).

6.0 Evaporative Emissions

Emissions of toxics from the evaporation of unburned fuel are estimated as fractions of total evaporative VOC. MOVES estimates toxic emission ratios for evaporative processes from nonroad gasoline engines (including gasoline-ethanol blends). Currently, the nonroad portion of MOVES does not estimate evaporative emissions (e.g. refueling natural gas leaks) from LPG or CNG engines[26] or evaporative, refueling or spillage emissions from diesel engines. This section documents the source of the toxic ratios used for evaporative emissions from nonroad gasoline engines.

6.1 Gasoline Engines

6.1.1 Vapor Venting and Refueling Emission Processes

Vapor venting processes in the nonroad portion of MOVES include diurnal fuel, hot soak, and running loss. Refueling emission processes in the nonroad portion of MOVES include spillage loss and displacement vapor loss. In absence of detailed data for nonroad engines, toxic fractions for these evaporative VOC emission processes were taken from onroad vehicles. Simple fractions for air toxics in evaporative non-permeation emissions were obtained from profiles developed for EPA by Environ Corporation, using data from the Auto/Oil program conducted in the early 1990's.[27] For convenience, toxic fractions are listed below in Table 22.

Table 22. Toxic fractions for evaporative VOC emissions, for vapor-venting and refueling processes

Pollutant	Ethanol Level	
	0.0% (E0)	10% (E10)
Ethanol	0.00000	0.11896
2,2,4-Trimethylpentane	0.01984	0.03354
Ethyl Benzene	0.02521	0.01721
N-Hexane	0.02217	0.02536
Toluene	0.09643	0.14336
Xylene	0.07999	0.06423
Benzene	0.03318	0.03187

6.1.2 Permeation

Permeation processes in the nonroad portion of MOVES include tank and hose permeation. In absence of detailed permeation data for nonroad engines, toxic fractions representing permeation emissions were taken from onroad vehicles. Work to characterize permeation emissions was conducted by Southwest Research Institute for EPA and the Coordinating Research Council in the CRC E-77-2b test program.[28] It is important to note that tank and hose permeation were not differentiated in the onroad portion of MOVES and the supporting studies. Thus, data on separate tank and hose permeation processes is unavailable and a single value is used in MOVES. The toxic fractions representing permeation emissions are listed below in Table 23.

Each of the toxic fractions listed in Table 23 are applied across all nonroad gasoline engine types.

Table 23. Toxic fractions representing permeation emissions as components of total VOC emissions

Pollutant	Ethanol Level	
	0.0% (E0)	10% (E10)
Ethanol	0.000	0.202
2,2,4-Trimethylpentane	0.036	0.024
Ethyl Benzene	0.003	0.001
N-Hexane	0.050	0.065
Toluene	0.110	0.101
Xylene	0.016	0.011
Benzene	0.025	0.023

7.0 Crankcase Running Exhaust Emissions

Crankcase emissions are modeled using the exhaust emissions ratios described in this document and ratios of crankcase to exhaust. Discussion of the crankcase to exhaust ratios used to estimate THC, CO, NOx, and PM crankcase emissions can be found in the light-duty[29] and heavy-duty[30] emission rate reports. In general, toxic crankcase emissions that are calculated as a ratio from VOC or from PM are computed as a fraction of the toxic exhaust emissions. The details on crankcase emissions are discussed in the following sections.

7.1 Organic Gas Aggregations and Air Toxic Emission Factors

Table 1 lists the VOC toxics modeled in MOVES2014a, which are also modeled for crankcase emission processes. As explained in Section 2.1 for exhaust emissions, MOVES2014a models nonroad crankcase VOC emissions by applying the multiplier in Tables 6 and 11 (for gasoline and diesel engines, respectively) to the THC emissions. Similarly, crankcase VOC toxics are calculated by multiplying crankcase VOC emissions by the VOC/NMHC ratios listed in Tables 5 and 10 for gasoline and diesel engines, respectively. Onroad crankcase VOC emission fractions are applied to the nonroad gasoline and diesel engine categories discussed in Sections 2.1 and 3.1 of this report.

7.2 Polycyclic Aromatic Hydrocarbons

Table 2 lists the gaseous phase PAH toxics modeled in MOVES2014a. The gaseous PAHs are modeled in a fashion similar to the VOC toxic emissions, using the multipliers listed in Tables 7 and 12 for gasoline and diesel engines, respectively.

Particle phase PAHs (based off of $PM_{2.5}$) are not modeled for crankcase emissions as the nonroad portion of the model does not currently model crankcase PM.

7.3 Metal and Dioxin Emissions

MOVES does not produce crankcase emission rates for metals that are not included in the speciation profiles such as arsenic, mercury and other metals listed in Table 4. Similarly, MOVES does not estimate dioxin and furan emissions from crankcase emissions. Because crankcase emissions are small in comparison to exhaust emissions, we assume that these emissions are negligible.

Appendix A. Development of Exhaust TOG and VOC Speciation Profiles for Spark-Ignition and Compression-Ignition Nonroad Engines

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1.0 Introduction

Exhaust emissions from nonroad engines or equipment vary based on engine/equipment type, control technology, fuel, and operating conditions. Characterizing the magnitude and chemical composition of these emissions is necessary for inventory and air quality modeling. To model the impact of air pollutant emissions, speciation profiles are used to distribute individual chemical compounds in total organic gas (TOG) emissions into emission estimates for individual species. However, speciation data for nonroad engines is limited, especially for engines with emission controls running on gasoline/ethanol blends and more recent diesel technologies.

In this document, we present the results of an extensive review and analysis of available speciation data for TOG. Our review concluded that the best available data sets for nonroad engines that had different levels of emission controls and were running on representative fuels were from two test programs conducted by Southwest Research Institute (SwRI), under contracts from EPA. Exhaust emissions data from these programs were used to create TOG speciation profiles for nonroad spark-ignition (SI) engines[3] and nonroad compression ignition (CI) engines.[4,5] Data from the SI engine test program provided the basis for profiles of uncontrolled 2-stroke and 4-stroke engines operating on gasoline (E0) and gasoline containing 10% ethanol by volume (E10). Data from the CI engine test programs using low and high sulfur diesel fuel provided the basis for profiles of pre-Tier 1, Tier 1, and Tier 2 engines with varying power levels. Profiles were developed for use in air quality modeling runs such as those done with the Community Multi-scale Air Quality (CMAQ) model and were submitted to EPA's database for TOG and particulate matter (PM) speciation profiles. This database, called SPECIATE, maintains the record of each profile including its referenced source, testing methods, a subjective rating of the quality of the data, and other detailed data that allow researchers to decide which profile is most suitable for model input.

2.0 Methods

2.1 Exhaust Emissions Data

2.1.1 Engines

Engines in the SI test program include those in Table 2-1. Seven small off-road engines (SOREs) were used to create E0 and E10 4-stroke uncatalyzed profiles. These engines include two mowers, two riding mowers, two generators and a blower (three non-handheld Class I, three non-handheld Class II, one handheld). Data on recreational vehicles from the SI test program, including two all-terrain vehicles (ATVs) and two nonroad motor cycles (NRMCs), were used to create E0 and E10 2-stroke uncatalyzed profiles. Engines in the CI test programs are listed in Table 2-2 and include a forklift truck, construction engines/equipment, and an agricultural tractor.

Table 2-1. Spark-Ignition Test Engines and Equipment

Type		SORE	SORE	SORE	SORE	SORE	SORE	SORE
Equipment	Make	MTD	Honda	MTD 638RL	Snapper	Briggs & Stratton	Honda	Makita
	Model Year	2006	2007	2007	2007	2004	2006	2007
	Model	11A-084F229	HRC 2163HXA	Yard machine 13A1762F229	S150X	Elite Series 6200 30386	EB11000	BHX2500
	Type	22" Mower	Mower	Riding Mower	Riding Mower	Generator	Generator	Blower
Engine	Make	Briggs & Stratton	Honda	Techumseh	Kawasaki	Briggs & Stratton	Honda	Makita
	Model	10T502158	GXV160	OV 358 EA	FH641V-ES25-R	1015499427	GX620KI	EHO25
	2-stroke or 4-stroke	4	4	4	4	4	4	4
	Three-way Catalyst	No	No	No	No	No	No	No

Type		NRMC	NRMC	ATV	ATV
Engine	Make	Honda	Kawasaki	Yamaha	Polaris
	Model	CR125	KX250	Blaster	Trailblazer
	Model Year	2007	2002	2006	2005
	2-stroke or 4-stroke	2	2	2	2
	Three-way Catalyst	No	No	No	No
	Oil Lubrication	Pre-mixed	Pre-mixed	Injected	Injected

Table 2-2. Compression-Ignition Test Engines

Intended Application	Manufacturer	Model	Model Year	Tier	hp	rpm
forklift truck	Kubota	V2203E	1999	1	50	2800
construction equipment	Cummins	QSL9	1999	1	330	2000
rubber-tired loader	Caterpillar	3408	1999	1	480	1800
motor grader	Deere	6068T	1996	0	160	2200
excavator	Cummins	M11C	1997	1	270	1700
agricultural tractor	Caterpillar	3196	2001	2	420	2100
telescoping boom excavator	Cummins	ISB190	2001	1	194	2300

2.1.2 Fuels

Test fuels for the SI test program included federal certification fuels (CERT1 and CERT2), fuels used in a concurrent California Air Resources Board (ARB) program which are similar to California Phase III fuel without ethanol (ARB E0), fuel being used for the California ARB program with ten percent ethanol (ARB E10-7), a modified ARB E10 fuel with 10-psi RVP (designated as ARB E10-10), and an EPA gasoline blend of E10. A brief description of the fuels is provided in Table 2-3 and the test properties of these fuels is included in Table 2-4.

Table 2-3. Fuel Used for SI Engine Testing

Fuels	Fuel description
CERT1	Federal Certification, non-oxygenated
CERT2	Federal Certification, non-oxygenated
ARB E0	Non-oxygenated gasoline
ARB E10-7	10% ethanol, RVP 7 psi
ARB E10-10	10% ethanol, RVP 10 psi by adding butane to ARB E10-7
EPA-E10	10% ethanol, RVP 9 psi

Table 2-4. SI Test Fuel Properties

	E0			E10			
Test fuel	ARB E0	CERT1	CERT2	ARB E10-7a	ARB E10-7b	ARB E10-10	EPA-E10
Ethanol (Wt%)	<0.2	<0.1	NP	9.65	9.98	9.69	9.39
RVP (psi)	7.15	8.98	9.2	6.96	6.76	9.79	8.99
T50 (deg F)	228	224	223	214	213	207	211
T90 (deg F)	304	309	318	315	314	313	319
Aromatics (Vol%)	31.78	31.5	27.9	22.08	24.92	22.66	24.7
Benzene (Wt%)	0.31	0.7*	NR	0.97	0.72*	0.70*	0.68
Sulfur Content (ppm)	<10	2.3	3.2	<10	2.8	4.6	21.9

NP = Not performed for this non-oxygenated fuel

NR = Not reported

* Benzene content reported as volume percent

Fuels used in the CI test programs were an emissions certification test grade Type-2D diesel fuel and a high-sulfur Nonroad-2D diesel fuel. The Type-2D fuel had a sulfur level of 390 ppm and the Nonroad-2D had a sulfur level of 2570 ppm. Additional fuel properties are described in Table 2-5. The high-sulfur diesel fuel was in compliance with EPA fuel sulfur regulations at the time of the test program. The Type-2D diesel fuel sulfur level complies with EPA diesel fuel sulfur standards (500 ppm) for nonroad engines as of 2007. Nonroad diesel fuel sulfur levels have been further tightened by the Tier 4 Nonroad Diesel Rule to 15 ppm starting in 2010 and fully phased in by 2015.

Table 2-5. CI Test Fuel Properties

Test fuel	Type-2D	Nonroad-2D
Sulfur, ppm	390	2570
Cetane Number	48.0	46.1
T50 (deg F)	505	511
T90 (deg F)	618	613
Total Aromatics (Vol%)	32.15	31.9
Saturates (Vol%)	66.05	67.45
Specific Gravity	0.8444	0.8507
API Gravity	36.1	34.8

2.1.3 Sample Collection and Analysis, Spark-Ignition Engines

Exhaust emission testing for the small SI engines was performed using modal test cycles applicable to the type of equipment. One complete emission test was performed with each test fuel using dilute exhaust test methodologies. Steady-state modal emissions tests were performed on the small SI engines. More detail on the steady-state operation modes used on these engines can be found in Table 18 of the SI test report.[3] All non-handheld engines were tested with the governor in control of load, and speed was controlled by the dynamometer according to 40CFR Part 1065.510 protocols. Handheld engine load and speed were controlled by the engine operator and dynamometer, respectively.

Testing for the ATVs and NRMCs was conducted using a Superflow CycleDyn Motorcycle and ATC eddy-current (chassis) dynamometer modified for vehicle-plus-driver weights as low as 153 kg (337 lbs). Each ATV and NRMC was tested using the Urban Dynamometer Drive Schedule (UDDS) drive cycle from 40 CFR, Part 86, Appendix I. The test cycle consists of two phases, each 1370 s long (7.5 miles). The first phase begins with a single cold-start UDDS. The two phases were separated by stopping the test vehicle for 10 minutes. Composite emission rates were calculated using weighting factors of 0.43 and 0.57 for the first (cold-start and running) and second phases (hot-start and running), respectively.

Regulated emissions were measured along with aldehydes, alcohols, ammonia, nitrous oxide, and speciated hydrocarbons. Exhaust samples were analyzed for the presence of more than 200 different exhaust species. Proportional dilute exhaust gas samples were collected in bags for the analysis of hydrocarbons. Four gas chromatography with flame ionization detector (GC-FID) procedures, using a method similar to the Phase II Auto-Oil method,[C] were used to identify and quantify C2-C4 species, C5-C12 species, benzene and toluene, and alcohols. The collection of alcohols was accomplished by bubbling a fraction of the sample through glass impingers. Aldehyde and ketone samples were collected on cartridges packed with silica gel impregnated with 2,4-dinitrophenylhydrazine (DHPH) and were extracted with acetonitrile. A high performance liquid chromatography (HPLC) procedure was used to analyze aldehydes and ketones.

2.1.4 Sample Collection and Analysis, Compression-Ignition Engines

The transient duty cycles used in testing each of these seven engines were the U.S. on-highway heavy-duty Federal Test Procedure (FTP) and the backhoe loader nonroad duty cycle (BHL). Engine emissions were sampled under transient operating conditions for each engine using a test cell control strategy developed for

[C] Coordinating Research Council (1997). Auto/Oil Air Quality Improvement Research Program Final Report

commanding dynamometer and throttle control for each engine over the FTP cycle. The on-highway FTP cycle ran 20 minutes, and the BHL cycle ran 16 minutes.

Steady-state engine tests were based on an 8-mode ISO Type-C1 weighting scheme. Calibration and sampling methods of the steady-state C1 test adhered to test procedures in CFR, Part 89, and generally satisfied ISO 8178-1 guidelines.

Prior to emissions testing, engines were run over a preparatory test cycle, followed by a 20-minute engine-off soak period. After engine soak, each transient emission test was run from a hot-start, utilizing procedures and sampling processes given in CFR 40, Part 86, Subpart N. Another 20-minute engine-off soak period separated any duplicate runs of a test cycle.

Measurements of unregulated emissions consisted of carbonyls, ammonia, N_2O, sulfate, and several C_1-C_{12} hydrocarbons. Proportional bag samples of dilute exhaust were analyzed via GC-FID to speciate hydrocarbons from C_1 through C_{12} using a method similar to the Phase II Auto-Oil method.[D] For carbonyls, an array of impingers was used during each emission test to capture gaseous samples of dilute exhaust for later analyses. Formaldehyde and acetaldehyde were measured using a DNPH (2,4-dinitrophenyl solution) technique, as outlined in CFR Title 40, Part 86. A liquid chromatograph was used to quantify additional aldehydes and ketones captured by the impingers in a DNPH solution.

2.2 Assignment of SPECIATE Identification Numbers for TOG Speciation Profiles

For use in the SPECIATE database and air quality modeling, each speciated compound must be assigned a unique identification number. SPECIATE identification numbers were matched to compounds in the TOG exhaust emission profiles using CAS numbers. For compounds that did not have a one-to-one match with a SPECIATE identification number, the most similar listed compound was used. Table 2-6 lists the SPECIATE substitutions used in developing the nonroad profiles.

Table 2-6. SPECIATE surrogates used for nonroad profiles

Original Chemical Analysis	**SPECIATE Substitution**
Dimethylbenzaldehyde	2,5-Dimethylbenzaldehyde
Tert-1-but-2-methylbenzene	1-Methyl-2-tert-butylbenzene
3,4-Dimethylcumene	1,3-Dimethyl-4-isopropylbenzene
Methylpropylbenzene	(1-Methylpropyl)benzene
Cis-1-methyl-2-ethylcyclopentane	Cis-1-ethyl-2-methylcyclopentane
Trans-1-methyl-2-ethylcyclopentane	Tran-1-ethyl-2-methylcyclopentane
3-Ethyl-cis-2-pentene	3-Ethyl-2-pentene
Cyclopentadiene	1,3-Cyclopentadiene
2,2-Dimethylpropane	Neopentane
2-Methylpropene	Isobutylene
2-Methylbutane	Isopentane

For some species that co-elute, the chromatography peak area was split equally between the two compounds by the contractor. For other species, the contractor noted co-elution but only reported one of the co-eluted compounds and assigned all mass to that species. In such cases, the mass was subsequently split equally

[D] E.R. Fanick (2005). Diesel Exhaust Standard – Phase II: CRC Project No. AVFL-10b. Final Report.

between the co-eluted compounds and the unreported species were added to the chemical list. The following were indicated as co-eluted species:

- 2,2-dimethylpentane and methylcyclopentane
- 3-methyl-3-ethyl-pentane and 3,4-dimethylhexane
- Cis-1,4-dimethylcyclohexane and trans-1,3-dimethylcyclohexane
- Propylcyclopentane and 2,6-dimethylheptane
- 2,5-dimethylheptane and 3,5-dimethylheptane
- Decane and isobutylbenzene
- n-butylbenzene and 1-methyl-4-n-propylbenzene
- Isobutyraldehyde and methyl ethyl ketone

Unknown hydrocarbons were reported by the lab according to carbon number as unidentified C5, C6, C7, C8, and C9-C12+. Reported designations were maintained in assigning specie identification numbers instead of combining unknowns into one specie identification number.

3.0 Speciation Profile Development

3.1 SI Engine Profiles

Four profiles were developed from the SI engine test program, one for each of the following engine/fuel combinations shown in Table 3-1:

- 4-stroke uncatalyzed engines running on E0
- 4-stroke uncatalyzed engines running on E10
- 2-stroke uncatalyzed engines running on E0
- 2-stroke uncatalyzed engines running on E10

A speciation profile comprised of weight percents for every compound was created for each individual test by dividing each compound's mass by the total mass of the all species. These individual test profiles were averaged within their respective engine/fuel categories to obtain a composite profile representing that particular engine/fuel combination. The number of tests for each composite profile are indicated in Table 3-1 (note that CERT1 and CERT2 test fuels are E0 fuels). Two tests, not shown in Table 3-1, were excluded from the 4-stroke E0 profile: the B&S walk behind mower test (1-E10-759) was missing seven low weight paraffins and olefins, and the Honda walk behind mower test (2-E0-776) was missing all alcohol data. All measurements outside the range of 3.5 standard deviations were evaluated as potential outliers. No outliers were identified in the SI engine profiles.

Table 3-1. Engine/Fuel Combinations Used for SI Engine Speciation Profile Development

	Engines	Tests	Fuels
4 stroke uncatalyzed, E0	SOREs	7	ARB E0
	SOREs	1	CERT2
4 stroke uncatalyzed, E10	SOREs	6	ARB E10-7
	SOREs	1	EPA-E10
2 stroke uncatalyzed, E0	ATV-Blaster	1	CERT1
	ATV-Polaris	1	CERT1
	NRMC-CR125	1	CERT1
	NRMC-Kawasaki	1	CERT1
2 stroke uncatalyzed, E10	ATV-Blaster	1	ARB E10-10
		1	ARB E10-10
		1	ARB E10-7
	ATV-Polaris	1	ARB E10-7
		1	ARB E10-10
	NRMC-CR125	1	ARB E10-7
		1	ARB E10-10
	NRMC-Kawasaki	1	ARB E10-7
		1	ARB E10-10

Several adjustments were made to individual compounds following a thorough quality assurance assessment of the composite profiles. First, due to the nature of the fuels used in the SI emissions testing, toluene was highly variable across both 2-stoke and 4-stroke uncatalyzed profiles (ranging from 0.05% to 12.48 %). As a result, we replaced the nonroad composite profile toluene values with values from pre-Tier 2 onroad vehicle profiles (from profiles 8750a and 8751a).[25] Specifically, toluene was adjusted to 8.64% for the E0 profiles and 7.77% for the E10 profiles. Second, the 1,3-butadiene values in the 4-stroke uncatalyzed E0 profiles were replaced with the composite E10 value because the E0 values were low for olefins. Third, 2,3-dimethylhexane in one of the 4-stroke E10 tests (the Makita blower) was zeroed out due to its abnormally high value (1408 mg/hp-hr, 7.6%) and erroneously strong influence (1%) on the composite profile. Finally, in the 2-stroke non-catalyst E0 profile, one test (the CR125) had an abnormally high fraction of 3-methylpentane (10.8% in the hot-start bag), causing the composite profile fraction to be subsequently high (2.5%). The composite profile was adjusted by replacing the high 3-methylpentane value in the hot-start CR125 test with the average value from the other 2-stroke E0 tests.

The profiles for each engine/fuel combination were recalculated following the adjustments outlined above, and the resulting profiles are listed in Table 4-3.

We note that there were emissions test data from 2-stroke catalyst engines, however we were unable to use these tests to create speciation profiles due to many inconsistencies and high values in the data. For example, cyclohexane E10 values were eight times higher than E0 values, 2,2,4-trimethylpentane decreased from E0 to E10 opposite the uncatalyzed profiles), and values of hexane, 3-methylheptane and 3-methyl-cis-2-pentene were abnormally high in the E10 profiles. Without additional test programs on catalyzed 2-stroke engines to validate these variable measurements, we decided to exclude these tests from our analysis.

3.2 CI Engine Profiles

Three profiles were developed from the CI engine test program by the following emission control categories:

- Pre-Tier 1 uncontrolled engines
- Tier 1 controlled engines
- Tier 2 controlled engines

While both CI engine steady state and transient operation tests are presented in this report, only the transient data would be used for NONROAD-MOVES because transient tests better represent real world conditions. In addition, we have a greater number of transient tests, allowing for greater confidence in the data. We initially looked at the breakpoint of 50 horsepower (37 kW) to differentiate low and high horsepower engines because the Tier 1 emission standards for 11 to 50 Hp engines are less stringent (NMHC + NOx g/hp-hr) than +50hp engines. However, differences in horsepower between profiles were insignificant and thus all Tier 1 engines were grouped together.

As with the SI engine profiles, a speciation profile was first created for each individual test by dividing each compound's mass by the total mass of the all species for that test. These profiles were averaged within their respective emission control/power categories to obtain a composite profile representing that particular control/power combination under steady state and transient operating conditions. The number of tests for each CI engine profile are indicated in Table 3-2. As discussed in Section 2.1.2, tests for each engine were performed on both a high sulfur fuel and a low sulfur fuel. To increase the robustness of the composite profiles, we doubled the number of samples by including tests on both fuel types after our analysis found that speciated compounds had similar weight percent values between high and low sulfur fuel tests (Table 3-3). After incorporating both high and low sulfur fuels, a standard deviation test was performed to identify potential outliers. All measurements outside the range of 3.5 standard deviations were evaluated as potential outliers. Outliers were addressed as described below.

Table 3-2. Engine Combinations Used for CI Engine Speciation Profile Development

	Transient Total Tests	**Rated Power (Hp, kW)**	**Model Year**	**Engines**
Pre-Tier 1	6	160hp 119kW	1996	Deere 6068T motor grader
Tier 1	36	270hp 201kW	1997	Cummins M11C excavator
		194hp 145kW	2001	Cummins ISB190 telescoping boom excavator
		330hp 261kW	1999	Cummins QSL9 construction equipment
		480hp 358kW	1999	Caterpillar 3408 rubber-tired loader
		50hp 37kW	1999	Kubota V2203E forklift truck
Tier 2	6	420hp 313kW	2001	Caterpillar 3196 agriculture tractor

Table 3-3. Regression comparing low and high sulfur diesel fuels

	R^2	Slope	95% confidence interval	
Pre-Tier 1	0.98	0.98	0.95	1.00
Tier 1	0.99	0.99	0.97	1.01
Tier 2	0.91	1.03	0.96	1.09

Following a quality assurance assessment of the initial transient profiles, several adjustments were made to individual compounds. Unusual variability was observed in the 1,3-butadiene tests across all profiles, so all weight percents were replaced with the current NONROAD CI engine exhaust weight percent of 0.18616%. The acetone mass in one Caterpillar 3196 high-sulfur fuel test (E12DBHL1) and one Kubota V2203E low-sulfur fuel test (KP2DFTP1) failed the standard deviation checks and were subsequently zeroed out (41.9 mg/hp-hr for the Caterpillar 3196 while all other similar tests were 0.0 mg/hp-hr; 28.1 mg/hp-hr for the Kubota V2203E while all other similar tests were 0-0.7 mg/hp-hr). One Caterpillar 3196 test (E12DFTP1) had an abnormally high propane value which was also zeroed out (19.54% where other tests were 0.00%). Finally, a different Caterpillar 3196 test (E12DBHL1) had an unrealistically high acetylene value (10.82% where the other tests averaged to 1.15%) which we also zeroed out.

The profiles for each emission control/power combination were recalculated following the adjustments outlined above, and the resulting profiles are listed in Table 4-9.

4.0 Results

Chemical comparisons between currently used onroad profiles and the profiles developed in this report are also detailed in the literature.6 The final composite SI speciation profiles are presented in Tables 4-1, 4-2, and 4-3. Table 4-1 shows percentages of compounds grouped by class. Table 4-2 shows percentages for 10 compounds of interest. Table 4-3 shows the complete profiles with all compounds and includes CAS and SPECIATE ID numbers. In a similar fashion, the composite CI speciation profiles are presented in Tables 4-4 through 4-9. Composite SI and CI VOC emission factors are presented in Tables 4-10 through 4-18.

Table 4-1. Composite SI TOG Profile Percentages by Compound Class

Compound	E0 % 4 stroke, noncatalyst	E0 % 2 stroke, noncatalyst	E10 % 4 stroke, noncatalyst	E10 % 2 stroke, noncatalyst
Paraffins	33.90	50.88	31.85	47.31
Aromatics	27.32	31.46	24.75	26.72
Olefins	33.76	11.79	35.76	12.98
Aldehyde/Ketones	3.25	0.85	3.06	1.21
Oxygenates	0.47	0.15	2.76	7.76
Unknowns	1.30	4.86	1.81	4.03

Table 4-2. Composite SI TOG Profile Percentages of Selected Compounds

Compound	E0 % 4 stroke	E0 % 2 stroke	E10 % 4 stroke	E10 % 2 stroke
Methane	15.89	1.70	15.40	1.74
Ethylene	8.94	1.79	10.11	1.94
Propylene	5.29	1.14	5.29	1.26
2,2,4-Trimethylpentane	3.76	7.94	4.70	12.72
2-Methylbutane	2.22	10.25	1.46	6.14
Toluene	8.64	8.64	7.77	7.77
m-& p-Xylene	3.58	6.30	4.49	5.27
o-Xylene	1.20	2.27	1.26	1.82
Ethylbenzene	1.79	3.37	1.37	2.18
2,3-Dimethylpentane	1.87	0.62	1.42	0.00

Table 4-3. Composite SI Organic Gas Exhaust Speciation Profiles Displayed as Weight Percentages of TOG

Specie ID	CAS Number	Compound	E0 % 4 stroke	E0 % 2 stroke	E10 % 4 stroke	E10 % 2 stroke
1	135-98-8	(1-methylpropyl)benzene	0.00E+00	3.33E-03	4.43E-02	3.23E-03
9	4259-00-1	1,1,2-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	3073-66-3	1,1,3-TRIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13	4516-69-2	1,1,3-TRIMETHYLCYCLOPENTANE	2.30E-02	0.00E+00	2.54E-02	0.00E+00
19	590-66-9	1,1-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	1638-26-2	1,1-DIMETHYLCYCLOPENTANE	3.20E-03	8.70E-03	3.16E-03	2.92E-03
21	16747-50-5	1,1-Methylethylcyclopentane	5.91E-04	1.86E-02	1.55E-03	1.90E-02
36	135-01-3	1,2 DIETHYLBENZENE	2.73E-02	8.83E-02	0.00E+00	7.61E-02
22	488-23-3	1,2,3,4-TETRAMETHYLBENZENE	1.50E-03	6.99E-02	4.05E-02	6.97E-02
23	527-53-7	1,2,3,5-TETRAMETHYLBENZENE	8.65E-02	1.29E-02	4.89E-02	1.16E-02
25	526-73-8	1,2,3-TRIMETHYLBENZENE	2.24E-01	2.09E-02	1.63E-01	6.39E-02
28	95-93-2	1,2,4,5-TETRAMETHYLBENZENE	1.44E-02	1.26E-01	8.82E-03	1.41E-01
29	877-44-1	1,2,4-TRIETHYLBENZENE	6.84E-04	2.32E-02	0.00E+00	2.02E-02
30	95-63-6	1,2,4-TRIMETHYLBENZENE	1.39E+00	2.10E+00	1.29E+00	2.00E+00
37	933-98-2	1,2-dimethyl-3-ethylbenzene	0.00E+00	5.66E-03	0.00E+00	4.09E-03
39	934-80-5	1,2-DIMETHYL-4-ETHYLBENZENE	1.25E-01	3.58E-02	9.44E-02	2.75E-02
42	463-49-0	1,2-PROPADIENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	102-25-0	1,3,5-TRIETHYLBENZENE	0.00E+00	2.42E-02	0.00E+00	1.84E-02
44	108-67-8	1,3,5-TRIMETHYLBENZENE	4.33E-01	7.52E-01	5.71E-01	7.21E-01
55	934-74-7	1,3,-DIMETHYL-5-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
46	106-99-0	1,3-BUTADIENE	1.02E+00	2.08E-01	1.02E+00	2.65E-01
51	141-93-5	1,3-DIETHYLBENZENE	6.40E-02	1.73E-01	6.40E-02	1.69E-01
52	2870-04-4	1,3-DIMETHYL-2-ETHYLBENZENE	6.25E-02	1.74E-02	2.50E-02	1.38E-02
53	874-41-9	1,3-DIMETHYL-4-ETHYLBENZENE	3.43E-02	7.90E-02	9.26E-02	7.72E-03
54	4706-89-2	1,3-dimethyl-4-isopropylbenzene	2.54E-02	0.00E+00	5.91E-02	0.00E+00
59	105-05-5	1,4-DIETHYLBENZENE	1.98E-02	4.10E-01	0.00E+00	3.91E-01
60	1758-88-9	1,4-DIMETHYL-2-ETHYLBENZENE	5.71E-02	2.50E-01	6.49E-02	2.40E-01
64	106-98-9	1-BUTENE	3.61E-01	1.17E-01	4.34E-01	1.27E-01
65	107-00-6	1-butyne	0.00E+00	0.00E+00	0.00E+00	0.00E+00

357	15890-40-1	1-CIS,2-TRANS,3-TRIMETHYLCYCLOPENTANE	3.53E-02	1.44E-01	5.17E-02	1.56E-01
996	872-05-9	1-DECENE	0.00E+00	1.52E-02	7.69E-02	1.36E-02
75	637-92-3	1-ethyltertbutylether	0.00E+00	0.00E+00	0.00E+00	0.00E+00
76	592-76-7	1-HEPTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
78	592-41-6	1-HEXENE	3.34E-02	9.29E-02	9.76E-02	1.08E-01
80	611-14-3	1-METHYL-2-ETHYLBENZENE	3.35E-01	6.14E-01	3.36E-01	4.93E-01
81	527-84-4	1-METHYL-2-ISOPROPYLBENZENE	1.77E-01	6.51E-02	2.66E-01	5.08E-02
84	1074-17-5	1-METHYL-2-N-PROPYLBENZENE	3.82E-02	3.65E-02	9.27E-02	2.82E-02
89	620-14-4	1-METHYL-3-ETHYLBENZENE	1.01E+00	1.81E+00	9.11E-01	1.53E+00
90	535-77-3	1-METHYL-3-ISOPROPYLBENZENE	2.83E-01	3.94E-02	2.22E-01	2.65E-02
92	1074-43-7	1-METHYL-3-N-PROPYLBENZENE	1.27E-01	2.20E-01	2.32E-01	1.84E-01
94	622-96-8	1-METHYL-4-ETHYLBENZENE	4.16E-01	7.70E-01	2.98E-01	6.37E-01
97	99-87-6	1-METHYL-4-ISOPROPYLBENZENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	1074-55-1	1-METHYL-4-N-PROPYLBENZENE	1.15E-01	4.37E-02	5.86E-02	2.33E-02
103	693-89-0	1-METHYLCYCLOPENTENE	1.42E-02	1.11E-01	6.36E-02	1.66E-01
106	124-11-8	1-NONENE	1.09E-01	1.74E-01	2.41E-02	6.89E-02
107	111-66-0	1-OCTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
108	109-67-1	1-pentene	0.00E+00	1.71E-01	0.00E+00	2.23E-01
607	71-23-8	1-Propanol	9.58E-02	0.00E+00	5.96E-02	0.00E+00
730	15890-40-1	1-TRANS-2-CIS-3-TRIMETHYLCYCLOPENTANE	7.23E-03	6.32E-02	1.77E-02	7.80E-02
1540	2815-58-9	1-TRANS-2-CIS-4-TRIMETHYLCYCLOPENTANE	0.00E+00	7.46E-02	0.00E+00	6.90E-02
112	464-06-2	2,2,3-TRIMETHYLBUTANE	2.46E-02	5.81E-02	4.54E-02	6.84E-02
113	564-02-3	2,2,3-TRIMETHYLPENTANE	4.21E-01	9.40E-01	2.99E-01	1.05E+00
117	16747-26-5	2,2,4-trimethylhexane	4.45E-03	2.56E-02	0.00E+00	1.93E-02
118	540-84-1	2,2,4-TRIMETHYLPENTANE	3.76E+00	7.94E+00	4.70E+00	1.27E+01
121	3522-94-9	2,2,5-TRIMETHYLHEXANE	3.08E-01	5.77E-01	5.06E-02	4.09E-02
122	75-83-2	2,2-DIMETHYLBUTANE	2.94E-02	9.06E-02	4.12E-02	6.98E-02
123	1071-26-7	2,2-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
124	590-73-8	2,2-DIMETHYLHEXANE	4.50E-03	9.91E-02	7.65E-03	8.83E-02
125	15869-87-1	2,2-DIMETHYLOCTANE	5.59E-02	9.31E-02	2.81E-02	5.55E-02
126	590-35-2	2,2-DIMETHYLPENTANE	6.08E-02	4.21E-01	2.16E-01	6.11E-01
127	463-82-1	2,2-DIMETHYLPROPANE (NEOPENTANE)	0.00E+00	8.52E-02	0.00E+00	7.04E-02
128	560-21-4	2,3,3-TRIMETHYLPENTANE	6.05E-01	1.45E+00	1.08E-01	2.08E-01
129	921-47-1	2,3,4-TRIMETHYLHEXANE	0.00E+00	1.98E-02	0.00E+00	2.04E-02
130	565-75-3	2,3,4-TRIMETHYLPENTANE	9.31E-01	2.40E+00	2.17E-01	6.65E-01
132	1069-53-0	2,3,5-TRIMETHYLHEXANE	4.82E-02	9.10E-02	1.16E-02	3.74E-02
135	10574-37-5	2,3-DIMETHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
136	79-29-8	2,3-DIMETHYLBUTANE	3.88E-01	7.34E-01	1.95E-01	5.40E-01
137	3074-71-3	2,3-DIMETHYLHEPTANE	0.00E+00	1.81E-02	0.00E+00	2.45E-02
138	584-94-1	2,3-DIMETHYLHEXANE	1.38E-01	0.00E+00	1.14E-02	1.29E-01
140	565-59-3	2,3-DIMETHYLPENTANE	1.87E+00	6.24E-01	1.42E+00	1.47E-03
141	107-39-1	2,4,4-TRIMETHYL-1-PENTENE	7.17E-03	8.99E-02	6.60E-02	1.07E-01
142	107-40-4	2,4,4-TRIMETHYL-2-PENTENE	0.00E+00	1.17E-02	5.20E-02	1.84E-02
143	16747-30-1	2,4,4-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
148	2213-23-2	2,4-DIMETHYLHEPTANE	4.42E-02	7.87E-02	2.31E-02	5.99E-02
149	589-43-5	2,4-DIMETHYLHEXANE	4.78E-01	1.29E+00	3.50E-01	1.14E+00
151	4032-94-4	2,4-DIMETHYLOCTANE	7.68E-03	5.93E-02	3.31E-02	6.70E-02
152	108-08-7	2,4-DIMETHYLPENTANE	1.09E+00	1.41E+00	3.29E-01	9.47E-01

155	2216-30-0	2,5-DIMETHYLHEPTANE	5.39E-02	8.94E-02	3.22E-02	6.76E-02
156	592-13-2	2,5-dimethylhexane	0.00E+00	2.37E-03	0.00E+00	0.00E+00
160	1072-05-5	2,6-DIMETHYLHEPTANE	0.00E+00	4.45E-03	0.00E+00	6.71E-03
170	503-17-3	2-butyne	0.00E+00	0.00E+00	0.00E+00	0.00E+00
511	78-79-5	2-METHYL-1,3-BUTADIENE	1.89E-01	1.09E-01	2.62E-01	1.43E-01
181	563-46-2	2-methyl-1-butene	0.00E+00	2.91E-01	0.00E+00	4.42E-01
2185	6094-02-6	2-METHYL-1-HEXENE	0.00E+00	2.66E-02	4.24E-03	2.97E-02
184	763-29-1	2-METHYL-1-PENTENE	3.34E-02	1.04E-01	9.76E-02	1.28E-01
185	513-35-9	2-METHYL-2-BUTENE	2.01E-01	5.86E-01	2.40E-01	7.56E-01
186	2738-19-4	2-methyl-2-hexene	0.00E+00	1.06E-01	1.32E-02	1.32E-01
187	625-27-4	2-METHYL-2-PENTENE	3.68E-02	1.31E-01	7.13E-02	1.84E-01
508	78-78-4	2-METHYLBUTANE (ISOPENTANE)	2.22E+00	1.02E+01	1.46E+00	6.14E+00
2568	03968-85-2	2-METHYLBUTYLBENZENE (sec AMYLBENZENE)	1.18E-02	1.55E-01	0.00E+00	1.54E-01
193	592-27-8	2-METHYLHEPTANE	2.17E-01	7.75E-01	2.07E-01	5.49E-01
194	591-76-4	2-METHYLHEXANE	0.00E+00	2.60E+00	0.00E+00	5.02E+00
198	3221-61-2	2-METHYLOCTANE	1.83E-01	6.15E-01	1.63E-01	4.70E-01
199	107-83-5	2-METHYLPENTANE	3.31E-01	1.73E+00	7.82E-01	2.32E+00
491	75-28-5	2-METHYLPROPANE (ISOBUTANE)	1.40E-01	2.24E-01	3.15E-02	1.58E-02
497	115-11-7	2-METHYLPROPENE (ISOBUTYLENE)	2.66E+00	7.48E-01	3.07E+00	1.02E+00
513	67-63-0	2-Propanol	1.42E-02	1.67E-02	4.77E-03	0.00E+00
203	558-37-2	3,3-DIMETHYL-1-BUTENE	1.80E-02	9.77E-03	3.83E-02	9.95E-03
205	4032-86-4	3,3-DIMETHYLHEPTANE	0.00E+00	3.17E-02	0.00E+00	3.74E-02
206	563-16-6	3,3-DIMETHYLHEXANE	2.53E-02	8.53E-02	4.40E-02	8.09E-02
208	562-49-2	3,3-DIMETHYLPENTANE	2.60E-02	9.62E-02	7.03E-03	4.08E-02
209	7385-78-6	3,4-DIMETHYL-1-PENTENE	8.31E-03	1.69E-02	1.29E-02	2.13E-02
211	922-28-1	3,4-DIMETHYLHEPTANE	0.00E+00	4.27E-02	0.00E+00	2.90E-02
212	583-48-2	3,4-DIMETHYLHEXANE	3.85E-02	8.67E-02	9.33E-03	7.15E-02
215	926-82-9	3,5-DIMETHYLHEPTANE	5.39E-02	8.94E-02	3.22E-02	6.76E-02
221	816-79-5	3-ethyl-2-pentene	0.00E+00	1.00E-02	0.00E+00	1.21E-02
226	619-99-8	3-ETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
229	617-78-7	3-ETHYLPENTANE	2.65E-02	2.14E-01	1.01E-01	3.27E-01
230	563-45-1	3-METHYL-1-BUTENE	4.18E-02	1.98E-01	7.99E-02	1.27E-01
231	3404-61-3	3-methyl-1-hexene	0.00E+00	1.91E-02	0.00E+00	1.98E-02
232	760-20-3	3-METHYL-1-PENTENE	3.09E-02	8.00E-02	4.21E-02	8.82E-02
233	1067-08-9	3-Methyl-3-ethyl-pentane	3.85E-02	8.67E-02	9.33E-03	7.15E-02
236	922-62-3	3-METHYL-CIS-2-PENTENE	3.20E-02	1.56E-01	6.75E-02	2.35E-01
242	1120-62-3	3-METHYLCYCLOPENTENE	3.41E-03	3.00E-03	1.85E-02	3.33E-03
244	589-81-1	3-METHYLHEPTANE	2.69E-01	1.20E+00	2.31E-01	7.25E-01
245	589-34-4	3-METHYLHEXANE	1.89E-01	1.57E+00	4.07E-01	1.35E+00
247	2216-33-3	3-METHYLOCTANE	1.14E-01	4.35E-01	9.49E-02	3.11E-01
248	96-14-0	3-METHYLPENTANE	2.01E-01	1.07E+00	5.36E-01	1.55E+00
239	616-12-6	3-METHYL-TRANS-2-PENTENE	3.70E-02	1.97E-01	9.19E-02	2.74E-01
240	3899-36-3	3-methyl-trans-3-hexene	0.00E+00	0.00E+00	0.00E+00	0.00E+00
253	1068-19-5	4,4-DIMETHYLHEPTANE	4.23E-03	9.56E-02	9.31E-03	7.20E-02
1471	2216-32-2	4-ETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
258	691-37-2	4-METHYL-1-PENTENE	0.00E+00	1.20E-03	0.00E+00	1.95E-02
260	691-38-3	4-METHYL-CIS-2-PENTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
264	589-53-7	4-METHYLHEPTANE	5.92E-02	7.29E-01	3.44E-02	1.76E-01
267	2216-34-4	4-methyloctane	0.00E+00	0.00E+00	0.00E+00	0.00E+00
262	674-76-0	4-METHYL-TRANS-2-PENTENE	5.18E-03	6.54E-02	0.00E+00	8.16E-02
279	75-07-0	Acetaldehyde	3.49E-01	1.01E-01	7.40E-01	3.28E-01

281	67-64-1	Acetone	2.48E-01	3.92E-02	2.04E-01	4.86E-02
282	74-86-2	ACETYLENE	1.35E+01	3.10E+00	1.30E+01	2.69E+00
283	107-02-8	Acrolein	3.05E-02	3.04E-02	3.71E-02	4.33E-02
301	100-52-7	Benzaldehyde	4.26E-01	1.06E-01	2.13E-01	6.51E-02
302	71-43-2	BENZENE	5.64E+00	1.36E+00	3.77E+00	1.23E+00
592	106-97-8	BUTANE	6.22E-01	1.69E+00	5.01E-01	1.17E+00
351	2207-01-4	CIS-1,2-DIMETHYLCYCLOHEXANE	3.55E-02	1.10E-01	3.63E-02	9.95E-02
360	1192-18-3	CIS-1,2-DIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
352	638-04-0	Cis-1,3-dimethylcyclohexane	0.00E+00	0.00E+00	0.00E+00	0.00E+00
353	2532-58-3	CIS-1,3-DIMETHYLCYCLOPENTANE	2.13E-02	6.81E-02	8.82E-02	1.91E-02
354	624-29-3	Cis-1,4-Dimethylcyclohexane	1.14E-03	2.59E-02	7.12E-03	2.71E-02
362	930-89-2	Cis-1-ethyl-2-methylcyclopentane	9.97E-03	8.48E-02	1.65E-02	6.56E-02
364	2613-66-3	CIS-1-METHYL-3-ETHYLCYCLOPENTANE	1.78E-02	4.71E-02	4.03E-02	5.83E-02
367	590-18-1	CIS-2-BUTENE	1.79E-01	7.69E-02	1.95E-01	1.04E-01
368	6443-92-1	CIS-2-HEPTENE	1.62E-02	5.13E-02	2.19E-02	5.69E-02
369	7688-21-3	CIS-2-HEXENE	2.40E-02	7.63E-02	2.06E-02	9.53E-02
370	7642-04-8	CIS-2-OCTENE	0.00E+00	7.55E-02	0.00E+00	1.26E-02
371	627-20-3	CIS-2-PENTENE	1.01E-01	2.15E-01	1.43E-01	2.81E-01
2616	7642-10-6	CIS-3-HEPTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
372	7642-09-3	CIS-3-HEXENE	5.50E-03	9.20E-02	2.78E-02	1.16E-01
373	20237-46-1	CIS-3-NONENE	0.00E+00	6.70E-03	0.00E+00	6.23E-03
382	4170-30-3	Crotonaldehyde	3.01E-02	1.91E-02	2.45E-02	2.35E-02
385	110-82-7	CYCLOHEXANE	5.26E-02	5.26E-02	5.31E-01	7.58E-02
388	110-83-8	CYCLOHEXENE	1.19E-01	2.77E-02	4.58E-02	3.71E-02
48	542-92-7	CYCLOPENTADIENE	3.47E-01	1.17E-01	3.92E-01	1.21E-01
390	287-92-3	CYCLOPENTANE	3.65E-02	7.45E-02	5.60E-02	1.04E-01
391	142-29-0	CYCLOPENTENE	2.94E-02	9.05E-02	7.18E-02	1.27E-01
598	124-18-5	DECANE	5.43E-02	7.60E-02	3.90E-02	5.86E-02
2735	108-20-3	DI-ISOPROPYL ETHER	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1712	5779-94-2	Dimethylbenzaldehyde	8.82E-02	1.99E-02	4.35E-02	2.37E-02
599	112-40-3	DODECANE	1.90E-02	8.03E-02	9.15E-03	5.22E-02
438	74-84-0	ETHANE	9.26E-01	2.46E-01	8.63E-01	2.86E-01
442	64-17-5	Ethanol	1.40E-01	5.67E-02	2.49E+00	7.63E+00
449	100-41-4	ETHYLBENZENE	1.79E+00	3.37E+00	1.37E+00	2.18E+00
450	1678-91-7	ETHYLCYCLOHEXANE	2.24E-02	1.75E-01	2.44E-02	1.07E-01
451	1640-89-7	ETHYLCYCLOPENTANE	1.95E-03	0.00E+00	1.13E-02	0.00E+00
452	74-85-1	ETHYLENE	8.94E+00	1.79E+00	1.01E+01	1.94E+00
465	50-00-0	Formaldehyde	1.61E+00	3.60E-01	1.45E+00	4.86E-01
600	142-82-5	HEPTANE	2.60E-01	1.15E+00	2.22E-01	6.18E-01
840	66-25-1	Hexanaldehyde	9.63E-04	1.89E-03	4.49E-03	1.91E-03
601	110-54-3	HEXANE	1.89E-01	7.55E-01	4.29E-01	6.99E-01
602	1077-16-3	HEXYLBENZENE	0.00E+00	1.78E-02	0.00E+00	2.84E-02
485	496-11-7	INDAN	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	538-93-2	ISOBUTYLBENZENE	5.12E-02	7.17E-02	3.68E-02	5.53E-02
2119	78-84-2	ISOBUTYRALDEHYDE	1.37E-02	9.61E-03	1.97E-02	9.95E-03
514	98-82-8	ISOPROPYLBENZENE (CUMENE)	9.56E-02	1.08E-01	3.83E-02	6.22E-02
2560	3875-51-2	ISOPROPYLCYCLOPENTANE	4.85E-03	1.13E-02	6.00E-03	3.37E-02
517	590-86-3	Isovaleraldehyde	5.06E-02	1.39E-02	4.42E-02	1.85E-02
522	1330-20-7	m-& p-XYLENE	3.58E+00	6.30E+00	4.49E+00	5.27E+00
2164	1334-78-7	m/p-Tolualdehyde	2.67E-01	4.58E-02	1.94E-01	7.57E-02

536	78-93-3	MEK	1.38E-02	9.61E-03	1.97E-02	9.95E-03
529	74-82-8	METHANE	1.59E+01	1.70E+00	1.54E+01	1.74E+00
531	67-56-1	Methanol	1.68E-01	7.63E-02	1.72E-01	1.29E-01
548	1634-04-4	Methyl t-butyl ether (MTBE)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
550	108-87-2	METHYLCYCLOHEXANE	8.24E-02	4.30E-01	2.30E-01	6.30E-01
551	96-37-7	METHYLCYCLOPENTANE	5.96E-02	4.13E-01	2.12E-01	5.99E-01
611	91-20-3	NAPHTHALENE	3.36E-02	5.84E-02	7.17E-02	4.58E-02
595	71-36-3	N-butyl alcohol	5.64E-02	0.00E+00	3.21E-02	0.00E+00
596	104-51-8	n-Butylbenzene	1.15E-01	2.97E-02	5.86E-02	2.33E-02
603	111-84-2	NONANE	1.70E-01	3.41E-01	6.08E-02	1.56E-01
606	538-68-1	N-PENT-BENZENE	2.62E-02	7.75E-02	2.77E-02	8.99E-02
608	103-65-1	n-PROPYLBENZENE	2.76E-01	6.70E-01	2.40E-01	4.75E-01
604	00111-65-9	OCTANE	2.21E-01	4.49E-01	1.44E-01	3.01E-01
1467	529-20-4	o-Tolualdehyde	6.87E-02	4.46E-02	3.34E-02	1.77E-02
620	95-47-6	o-XYLENE	1.20E+00	2.27E+00	1.26E+00	1.82E+00
605	109-66-0	PENTANE	3.33E-01	8.44E-01	3.21E-01	8.67E-01
671	74-98-6	PROPANE	2.68E-01	4.51E-02	7.13E-02	3.05E-02
673	123-38-6	Propionaldehyde	4.07E-02	4.94E-02	3.43E-02	5.10E-02
677	2040-96-2	Propylcyclopentane	0.00E+00	2.99E-03	0.00E+00	6.71E-03
678	115-07-1	PROPYLENE	5.29E+00	1.14E+00	5.29E+00	1.26E+00
109	74-99-7	PROPYNE	3.60E-03	2.27E-02	0.00E+00	1.88E-02
698	100-42-5	STYRENE	7.93E-01	2.18E-01	5.86E-01	1.73E-01
701	994-05-8	T-amylmethylether	0.00E+00	0.00E+00	0.00E+00	0.00E+00
86	1074-92-6	TERT-1-BUT-2-METHYLBENZENE	3.58E-03	1.29E-01	3.00E-02	1.57E-01
63	98-19-1	TERT-1-BUT-3,5-DIMETHYLBENZENE	2.24E-03	1.16E-01	7.28E-04	1.36E-01
2329	7364-19-4	TERT-1-BUTYL-4-ETHYLBENZENE	0.00E+00	5.62E-02	2.33E-02	6.05E-02
703	98-06-6	TERT-BUTYLBENZENE	0.00E+00	2.98E-02	0.00E+00	3.14E-02
717	108-88-3	TOLUENE	8.64E+00	8.64E+00	7.77E+00	7.77E+00
724	6876-23-9	TRANS-1,2-DIMETHYLCYCLOHEXANE	5.85E-03	3.84E-01	2.20E-02	1.73E-01
725	822-50-4	TRANS-1,2-DIMETHYLCYCLOPENTANE	2.86E-02	1.01E-01	2.88E-02	9.91E-02
726	2207-03-6	TRANS-1,3-DIMETHYLCYCLOHEXANE	1.14E-03	3.07E-02	7.12E-03	3.03E-02
727	1759-58-6	TRANS-1,3-DIMETHYLCYCLOPENTANE	3.23E-03	2.27E-01	0.00E+00	3.52E-01
729	2207-04-7	TRANS-1,4-DIMETHYLCYCLOHEXANE	0.00E+00	9.26E-03	9.87E-03	2.39E-02
1586	930-90-5	Trans-1-ethyl-2-methyl-cyclopentane	1.60E-03	9.08E-02	2.66E-02	1.12E-01
736	2613-65-2	TRANS-1-METHYL-3-ETHYLCYCLOPENTANE	0.00E+00	1.05E-01	2.55E-02	1.37E-01
737	624-64-6	TRANS-2-BUTENE	3.20E-01	2.04E-01	2.53E-01	2.28E-01
739	14686-13-6	TRANS-2-HEPTENE	1.23E-02	5.96E-02	2.47E-02	6.73E-02
740	4050-45-7	TRANS-2-HEXENE	1.29E-02	1.40E-01	4.27E-02	1.78E-01
2244	6434-78-2	TRANS-2-NONENE	0.00E+00	1.25E-02	0.00E+00	7.99E-03
741	13389-42-9	TRANS-2-OCTENE	6.34E-03	8.23E-02	4.15E-02	1.11E-01
742	646-04-8	TRANS-2-PENTENE	3.34E-02	3.75E-01	9.06E-02	4.91E-01
743	14686-14-7	TRANS-3-HEPTENE	7.30E-04	8.62E-02	2.57E-02	1.09E-01
744	13269-52-8	TRANS-3-HEXENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
745	20063-92-7	TRANS-3-NONENE	0.00E+00	4.49E-02	1.18E-02	5.13E-02
746	14850-23-8	Trans-4-octene	0.00E+00	5.47E-02	0.00E+00	4.55E-02
610	1120-21-4	UNDECANE	3.12E-02	1.14E-01	3.21E-02	1.08E-01

1989	#N/A	UNIDENTIFIED C5 OLEFINS	0.00E+00	1.35E-02	0.00E+00	8.74E-03
1999	#N/A	UNIDENTIFIED C6	1.32E-01	7.24E-02	1.57E-01	6.99E-02
2005	#N/A	UNIDENTIFIED C7	1.03E-01	7.53E-01	9.89E-02	2.70E-01
2011	#N/A	UNIDENTIFIED C8	1.99E-03	1.63E-01	8.50E-03	1.17E-01
327	#N/A	UNIDENTIFIED C9-C12+	1.06E+00	3.86E+00	1.55E+00	3.56E+00
845	110-62-3	Valeraldehyde	1.34E-02	4.47E-03	4.39E-03	4.73E-03

Table 4-4. Composite Transient CI TOG Profile Percentages by Compound Class

Compound	Pre-Tier 1	Tier 1	Tier 2
Paraffins	16.55	17.66	17.69
Aromatics	11.80	6.48	9.37
Olefins	26.39	30.45	22.67
Aldehydes/Ketones	39.72	43.96	44.36
Oxygenates	0.00	0.00	0.00
Unknowns	5.54	1.46	5.91

Table 4-5. Composite Transient CI TOG Profile Percentages of Selected Compounds

Compound	Pre-Tier 1	Tier 1	Tier 2
Methane	1.74	7.09	7.95
Ethylene	16.65	18.94	17.42
Propylene	0.00	3.79	0.00
2,2,4-Trimethylpentane	0.78	0.65	0.61
2-Methylbutane	0.00	0.49	0.00
Toluene	1.17	1.97	3.20
m-& p-Xylene	1.48	1.09	1.07
o-Xylene	0.70	0.41	0.00
Ethylbenzene	0.91	0.36	0.39
2,3-Dimethylpentane	0.09	0.14	0.26

Table 4-6. Composite Transient Cycle CI Organic Gas Exhaust Speciation Profiles Displayed as Weight Percentages of TOG

CAS Number	COMPOUND	Pre-Tier 1	Tier 1	Tier 2
135-98-8	(1-methylpropyl)benzene	0.00E+00	0.00E+00	0.00E+00
4259-00-1	1,1,2-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
3073-66-3	1,1,3-TRIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
4516-69-2	1,1,3-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
590-66-9	1,1-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
1638-26-2	1,1-DIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
16747-50-5	1,1-Methylethylcyclopentane	0.00E+00	0.00E+00	0.00E+00
135-01-3	1,2 DIETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
488-23-3	1,2,3,4-TETRAMETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00

527-53-7	1,2,3,5-TETRAMETHYLBENZENE	1.10E-01	3.03E-02	0.00E+00
526-73-8	1,2,3-TRIMETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
95-93-2	1,2,4,5-TETRAMETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
877-44-1	1,2,4-TRIETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
95-63-6	1,2,4-TRIMETHYLBENZENE	3.79E-01	2.34E-02	0.00E+00
933-98-2	1,2-DIMETHYL-3-ETHYLBENZENE	0.00E+00	1.74E-02	0.00E+00
934-80-5	1,2-DIMETHYL-4-ETHYLBENZENE	3.95E-02	6.87E-02	0.00E+00
463-49-0	1,2-PROPADIENE	0.00E+00	0.00E+00	0.00E+00
102-25-0	1,3,5-TRIETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
108-67-8	1,3,5-TRIMETHYLBENZENE	4.41E-01	0.00E+00	0.00E+00
934-74-7	1,3,-DIMETHYL-5-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
106-99-0	1,3-BUTADIENE	1.86E-01	1.86E-01	1.86E-01
141-93-5	1,3-DIETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
2870-04-4	1,3-DIMETHYL-2-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
874-41-9	1,3-DIMETHYL-4-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
4706-89-2	1,3-dimethyl-4-isopropylbenzene	0.00E+00	0.00E+00	0.00E+00
105-05-5	1,4-DIETHYLBENZENE	4.89E-01	2.28E-02	0.00E+00
1758-88-9	1,4-DIMETHYL-2-ETHYLBENZENE	9.40E-02	3.15E-03	0.00E+00
106-98-9	1-BUTENE	0.00E+00	2.98E-01	0.00E+00
107-00-6	1-BUTYNE	0.00E+00	0.00E+00	0.00E+00
15890-40-1	1-CIS,2-TRANS,3-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
872-05-9	1-DECENE	0.00E+00	0.00E+00	0.00E+00
637-92-3	1-ethyltertbutylether	0.00E+00	0.00E+00	0.00E+00
592-76-7	1-HEPTENE	0.00E+00	0.00E+00	0.00E+00
592-41-6	1-HEXENE	6.44E-01	4.10E-01	1.48E-01
611-14-3	1-METHYL-2-ETHYLBENZENE	2.85E-01	3.28E-03	0.00E+00
527-84-4	1-METHYL-2-ISOPROPYLBENZENE	3.85E-01	1.04E-01	0.00E+00
1074-17-5	1-METHYL-2-N-PROPYLBENZENE	0.00E+00	0.00E+00	0.00E+00
620-14-4	1-METHYL-3-ETHYLBENZENE	4.15E-01	1.47E-02	0.00E+00
535-77-3	1-METHYL-3-ISOPROPYLBENZENE	0.00E+00	7.96E-02	0.00E+00
1074-43-7	1-METHYL-3-N-PROPYLBENZENE	0.00E+00	0.00E+00	0.00E+00
622-96-8	1-METHYL-4-ETHYLBENZENE	2.43E-01	0.00E+00	0.00E+00
99-87-6	1-METHYL-4-ISOPROPYLBENZENE	0.00E+00	0.00E+00	0.00E+00
1074-55-1	1-METHYL-4-N-PROPYLBENZENE	2.51E-01	1.16E-02	0.00E+00
693-89-0	1-METHYLCYCLOPENTENE	3.48E-01	0.00E+00	0.00E+00
124-11-8	1-NONENE	7.74E-01	9.19E-02	0.00E+00
111-66-0	1-OCTENE	0.00E+00	0.00E+00	0.00E+00
109-67-1	1-PENTENE	1.27E+00	5.46E-01	2.22E-01
15890-40-1	1-TRANS-2-CIS-3-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
2815-58-9	1-TRANS-2-CIS-4-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
464-06-2	2,2,3-TRIMETHYLBUTANE	6.62E-01	4.47E-03	0.00E+00
564-02-3	2,2,3-TRIMETHYLPENTANE	0.00E+00	2.56E-01	0.00E+00
16747-26-5	2,2,4-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
540-84-1	2,2,4-TRIMETHYLPENTANE	7.78E-01	6.49E-01	7.27E-01

3522-94-9	2,2,5-TRIMETHYLHEXANE	0.00E+00	4.14E-02	0.00E+00
75-83-2	2,2-DIMETHYLBUTANE	3.52E-02	1.69E-01	0.00E+00
1071-26-7	2,2-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
590-73-8	2,2-DIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
15869-87-1	2,2-DIMETHYLOCTANE	4.50E-01	1.72E-02	0.00E+00
590-35-2	2,2-DIMETHYLPENTANE	1.84E-02	5.65E-02	5.39E-02
463-82-1	2,2-DIMETHYLPROPANE (NEOPENTANE)	0.00E+00	8.29E-02	0.00E+00
560-21-4	2,3,3-TRIMETHYLPENTANE	7.75E-02	4.07E-01	3.77E-01
921-47-1	2,3,4-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
565-75-3	2,3,4-TRIMETHYLPENTANE	2.50E-01	6.46E-02	4.56E-01
1069-53-0	2,3,5-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
10574-37-5	2,3-DIMETHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
79-29-8	2,3-DIMETHYLBUTANE	0.00E+00	1.55E-01	0.00E+00
3074-71-3	2,3-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
584-94-1	2,3-DIMETHYLHEXANE	0.00E+00	3.12E-01	0.00E+00
565-59-3	2,3-DIMETHYLPENTANE	8.81E-02	1.38E-01	2.92E-01
107-39-1	2,4,4-TRIMETHYL-1-PENTENE	0.00E+00	0.00E+00	0.00E+00
107-40-4	2,4,4-TRIMETHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
16747-30-1	2,4,4-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
2213-23-2	2,4-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
589-43-5	2,4-DIMETHYLHEXANE	4.93E-01	1.06E-01	0.00E+00
4032-94-4	2,4-DIMETHYLOCTANE	5.29E-01	5.34E-02	0.00E+00
108-08-7	2,4-DIMETHYLPENTANE	1.90E-01	4.33E-01	3.64E-01
2216-30-0	2,5-DIMETHYLHEPTANE	2.19E-01	3.65E-02	0.00E+00
592-13-2	2,5-DIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
1072-05-5	2,6-DIMETHYLHEPTANE	5.40E-01	1.72E-01	9.92E-02
503-17-3	2-BUTYNE	0.00E+00	0.00E+00	0.00E+00
78-79-5	2-METHYL-1,3-BUTADIENE	9.20E-02	3.21E-01	0.00E+00
563-46-2	2-METHYL-1-BUTENE	2.65E-01	1.76E-01	5.69E-01
6094-02-6	2-METHYL-1-HEXENE	0.00E+00	0.00E+00	0.00E+00
763-29-1	2-METHYL-1-PENTENE	6.44E-01	4.10E-01	1.48E-01
513-35-9	2-METHYL-2-BUTENE	0.00E+00	9.71E-02	2.96E-01
2738-19-4	2-METHYL-2-HEXENE	0.00E+00	0.00E+00	0.00E+00
625-27-4	2-METHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
78-78-4	2-METHYLBUTANE (ISOPENTANE)	0.00E+00	4.93E-01	0.00E+00
03968-85-2	2-METHYLBUTYLBENZENE (sec AMYLBENZENE)	0.00E+00	0.00E+00	0.00E+00
592-27-8	2-METHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
591-76-4	2-METHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
3221-61-2	2-METHYLOCTANE	1.12E+00	1.92E-01	0.00E+00
107-83-5	2-METHYLPENTANE	1.46E-01	2.72E-01	2.19E-01
75-28-5	2-METHYLPROPANE (ISOBUTANE)	0.00E+00	4.46E-01	6.57E-01
115-11-7	2-METHYLPROPENE (ISOBUTYLENE)	3.41E-01	7.38E-01	0.00E+00
558-37-2	3,3-DIMETHYL-1-BUTENE	0.00E+00	0.00E+00	0.00E+00
4032-86-4	3,3-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00

563-16-6	3,3-DIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
562-49-2	3,3-DIMETHYLPENTANE	0.00E+00	0.00E+00	0.00E+00
7385-78-6	3,4-DIMETHYL-1-PENTENE	0.00E+00	1.45E-02	0.00E+00
922-28-1	3,4-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
583-48-2	3,4-DIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
926-82-9	3,5-DIMETHYLHEPTANE	2.19E-01	3.65E-02	0.00E+00
816-79-5	3-ETHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
619-99-8	3-ETHYLHEXANE	1.11E-01	2.44E-02	0.00E+00
617-78-7	3-ETHYLPENTANE	0.00E+00	0.00E+00	0.00E+00
563-45-1	3-METHYL-1-BUTENE	0.00E+00	0.00E+00	0.00E+00
3404-61-3	3-METHYL-1-HEXENE	0.00E+00	0.00E+00	0.00E+00
760-20-3	3-METHYL-1-PENTENE	0.00E+00	0.00E+00	0.00E+00
1067-08-9	3-Methyl-3-ethyl-pentane	0.00E+00	0.00E+00	0.00E+00
922-62-3	3-METHYL-CIS-2-PENTENE	0.00E+00	1.56E-02	0.00E+00
1120-62-3	3-METHYLCYCLOPENTENE	0.00E+00	0.00E+00	0.00E+00
589-81-1	3-METHYLHEPTANE	0.00E+00	2.19E-02	1.92E-01
589-34-4	3-METHYLHEXANE	1.00E-01	9.25E-02	0.00E+00
2216-33-3	3-METHYLOCTANE	5.97E-01	7.07E-02	1.98E-01
96-14-0	3-METHYLPENTANE	5.51E-01	6.93E-01	3.71E-02
616-12-6	3-METHYL-TRANS-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
3899-36-3	3-METHYL-TRANS-3-HEXENE	0.00E+00	0.00E+00	0.00E+00
1068-19-5	4,4-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
2216-32-2	4-ETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
691-37-2	4-METHYL-1-PENTENE	2.62E-01	4.97E-02	3.84E-01
691-38-3	4-METHYL-CIS-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
589-53-7	4-METHYLHEPTANE	3.11E-01	2.48E-02	0.00E+00
2216-34-4	4-METHYLOCTANE	0.00E+00	0.00E+00	0.00E+00
674-76-0	4-METHYL-TRANS-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
75-07-0	ACETALDEHYDE	7.18E+00	7.14E+00	9.51E+00
67-64-1	ACETONE	1.89E+00	1.04E+00	0.00E+00
74-86-2	ACETYLENE	2.91E+00	3.41E+00	1.12E+00
107-02-8	ACROLEIN	2.92E+00	1.47E+00	1.70E+00
100-52-7	BENZALDEHYDE	3.49E-01	8.94E-01	7.02E-01
71-43-2	BENZENE	1.88E+00	1.97E+00	5.07E+00
106-97-8	BUTANE	3.36E-01	9.72E-01	5.47E-01
2207-01-4	CIS-1,2-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
1192-18-3	CIS-1,2-DIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
638-04-0	CIS-1,3-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
2532-58-3	CIS-1,3-DIMETHYLCYCLOPENTANE	2.31E-01	3.48E-02	0.00E+00
624-29-3	Cis-1,4-Dimethylcyclohexane	0.00E+00	0.00E+00	0.00E+00
930-89-2	Cis-1-ethyl-2-methylcyclopentane	3.52E-02	0.00E+00	0.00E+00
2613-66-3	CIS-1-METHYL-3-ETHYLCYCLOPENTANE	6.16E-01	2.47E-01	0.00E+00
590-18-1	CIS-2-BUTENE	0.00E+00	0.00E+00	0.00E+00
6443-92-1	CIS-2-HEPTENE	0.00E+00	1.76E-01	0.00E+00

7688-21-3	CIS-2-HEXENE	0.00E+00	0.00E+00	0.00E+00
7642-04-8	CIS-2-OCTENE	0.00E+00	0.00E+00	0.00E+00
627-20-3	CIS-2-PENTENE	0.00E+00	2.35E-02	0.00E+00
7642-10-6	CIS-3-HEPTENE	0.00E+00	0.00E+00	0.00E+00
7642-09-3	CIS-3-HEXENE	0.00E+00	2.48E-02	0.00E+00
20237-46-1	CIS-3-NONENE	0.00E+00	0.00E+00	0.00E+00
4170-30-3	CROTONALDEHYDE	1.94E+00	3.85E+00	3.16E+00
110-82-7	CYCLOHEXANE	9.16E-02	0.00E+00	0.00E+00
110-83-8	CYCLOHEXENE	3.93E-01	1.15E-01	0.00E+00
542-92-7	CYCLOPENTADIENE	0.00E+00	8.87E-03	0.00E+00
287-92-3	CYCLOPENTANE	2.02E-01	3.75E-02	0.00E+00
142-29-0	CYCLOPENTENE	4.34E-02	3.71E-02	0.00E+00
124-18-5	DECANE	1.85E-01	2.55E-02	0.00E+00
108-20-3	DI-ISOPROPYL ETHER	0.00E+00	0.00E+00	0.00E+00
5779-94-2	DIMETHYLBENZALDEHYDE	1.42E-01	2.77E-01	3.90E-01
112-40-3	DODECANE	4.43E-01	1.12E-01	0.00E+00
74-84-0	ETHANE	1.26E-01	4.66E-01	0.00E+00
64-17-5	ETHANOL	0.00E+00	0.00E+00	0.00E+00
100-41-4	ETHYLBENZENE	9.09E-01	3.56E-01	3.87E-01
1678-91-7	ETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
1640-89-7	ETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
74-85-1	ETHYLENE	1.66E+01	1.89E+01	1.84E+01
50-00-0	FORMALDEHYDE	1.99E+01	2.03E+01	2.66E+01
142-82-5	HEPTANE	2.63E-01	9.25E-02	0.00E+00
66-25-1	HEXANALDEHYDE	2.09E-01	2.20E-01	0.00E+00
110-54-3	HEXANE	2.24E-01	2.45E-01	0.00E+00
1077-16-3	HEXYLBENZENE	0.00E+00	0.00E+00	0.00E+00
496-11-7	INDAN	0.00E+00	0.00E+00	0.00E+00
538-93-2	ISOBUTYLBENZENE	1.77E-01	2.40E-02	0.00E+00
78-84-2	ISOBUTYRALDEHYDE	6.16E-01	7.02E-01	8.43E-01
98-82-8	ISOPROPYLBENZENE (CUMENE)	3.70E-01	7.32E-02	0.00E+00
3875-51-2	ISOPROPYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
590-86-3	ISOVALERALDEHYDE	6.75E-01	4.90E-01	0.00E+00
1330-20-7	m-& p-XYLENE	1.48E+00	1.09E+00	1.07E+00
1334-78-7	M/P-TOLUALDEHYDE	1.36E+00	1.75E+00	6.78E-01
78-93-3	MEK	6.16E-01	7.07E-01	8.43E-01
74-82-8	METHANE	1.74E+00	7.09E+00	8.28E+00
67-56-1	METHANOL	0.00E+00	0.00E+00	0.00E+00
1634-04-4	Methyl t-butyl ether	0.00E+00	0.00E+00	0.00E+00
108-87-2	METHYLCYCLOHEXANE	3.48E-01	2.56E-01	0.00E+00
96-37-7	METHYLCYCLOPENTANE	1.84E-02	5.51E-02	5.39E-02
91-20-3	NAPHTHALENE	4.74E-02	5.42E-02	0.00E+00
71-36-3	N-butyl alcohol	0.00E+00	0.00E+00	0.00E+00
104-51-8	n-Butylbenzene	2.51E-01	1.16E-02	0.00E+00

111-84-2	NONANE	2.23E+00	4.19E-01	0.00E+00
538-68-1	N-PENT-BENZENE	4.52E-02	0.00E+00	0.00E+00
103-65-1	n-PROPYLBENZENE	9.57E-01	1.95E-02	0.00E+00
00111-65-9	OCTANE	7.49E-01	3.62E-01	2.29E-01
529-20-4	O-TOLUALDEHYDE	1.09E-01	6.03E-01	0.00E+00
95-47-6	o-XYLENE	6.97E-01	4.09E-01	0.00E+00
109-66-0	PENTANE	1.17E-01	6.81E-01	1.56E+00
74-98-6	PROPANE	6.28E-02	5.71E-01	1.48E-01
123-38-6	PROPIONALDEHYDE	1.39E+00	3.55E+00	1.99E+00
2040-96-2	Propylcyclopentane	5.40E-01	1.72E-01	9.92E-02
115-07-1	PROPYLENE	0.00E+00	3.79E+00	0.00E+00
74-99-7	PROPYNE	0.00E+00	0.00E+00	0.00E+00
100-42-5	STYRENE	0.00E+00	0.00E+00	0.00E+00
994-05-8	T-AMYLMETHYLETHER	0.00E+00	0.00E+00	0.00E+00
1074-92-6	TERT-1-BUT-2-METHYLBENZENE	3.52E-01	4.12E-02	0.00E+00
98-19-1	TERT-1-BUT-3,5-DIMETHYLBENZENE	3.41E-01	8.15E-02	0.00E+00
7364-19-4	TERT-1-BUTYL-4-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
98-06-6	TERT-BUTYLBENZENE	0.00E+00	0.00E+00	0.00E+00
108-88-3	TOLUENE	1.17E+00	1.97E+00	3.43E+00
6876-23-9	TRANS-1,2-DIMETHYLCYCLOHEXANE	7.14E-02	0.00E+00	0.00E+00
822-50-4	TRANS-1,2-DIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
2207-03-6	TRANS-1,3-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
1759-58-6	TRANS-1,3-DIMETHYLCYCLOPENTANE	0.00E+00	8.59E-03	0.00E+00
2207-04-7	TRANS-1,4-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
930-90-5	Trans-1-ethyl-2-methyl-cyclopentane	0.00E+00	0.00E+00	0.00E+00
2613-65-2	TRANS-1-METHYL-3-ETHYLCYCLOPENTANE	0.00E+00	2.88E-02	0.00E+00
624-64-6	TRANS-2-BUTENE	1.50E+00	4.79E-01	0.00E+00
14686-13-6	TRANS-2-HEPTENE	0.00E+00	8.08E-03	0.00E+00
4050-45-7	TRANS-2-HEXENE	0.00E+00	6.71E-03	0.00E+00
6434-78-2	TRANS-2-NONENE	0.00E+00	0.00E+00	0.00E+00
13389-42-9	TRANS-2-OCTENE	0.00E+00	6.58E-02	0.00E+00
646-04-8	TRANS-2-PENTENE	7.47E-02	3.72E-03	5.32E-01
14686-14-7	TRANS-3-HEPTENE	0.00E+00	0.00E+00	0.00E+00
13269-52-8	TRANS-3-HEXENE	0.00E+00	0.00E+00	0.00E+00
20063-92-7	TRANS-3-NONENE	0.00E+00	0.00E+00	0.00E+00
14850-23-8	TRANS-4-OCTENE	0.00E+00	9.29E-03	0.00E+00
1120-21-4	UNDECANE	4.41E-01	2.65E-01	7.61E-01
	UNIDENTIFIED C5 OLEFINS	0.00E+00	1.08E-01	0.00E+00
	UNIDENTIFIED C6	4.50E-01	5.63E-01	0.00E+00
	UNIDENTIFIED C7	4.60E-02	5.85E-02	0.00E+00
	UNIDENTIFIED C8	3.95E-02	2.82E-02	0.00E+00
	UNIDENTIFIED C9-C12+	5.00E+00	6.98E-01	6.08E+00
110-62-3	VALERALDEHYDE	4.53E-01	9.24E-01	1.85E-01

Table 4-7. Composite SI VOC Profile Percentages by Compound Class

Compound	E0 % 4 stroke	E0 % 2 stroke	E10 % 4 stroke	E10 % 2 stroke
Paraffins	20.96	50.01	18.95	46.31
Aromatics	31.61	31.97	28.46	27.15
Olefins	41.57	12.07	43.56	13.29
Aldehyde/Ketones	3.68	0.83	3.47	1.19
Oxygenates	0.58	0.15	3.35	7.94
Unknowns	1.60	4.97	2.20	4.12

Table 4-8. Composite SI VOC Profile Percentages of Selected Compounds

Compound	E0 % 4 stroke	E0 % 2 stroke	E10 % 4 stroke	E10 % 2 stroke
Formaldehyde	1.98	0.37	1.76	0.50
Acetaldehyde	0.43	0.10	0.90	0.34
Ethylene	11.00	1.83	12.32	1.99
Propylene	6.51	1.17	6.44	1.30
2,2,4-Trimethylpentane	4.61	8.11	5.72	13.01
2-Methylbutane	2.73	10.47	1.79	6.28
Toluene	8.64	8.64	7.77	7.77
m-& p-Xylene	4.40	6.44	5.46	5.39
o-Xylene	1.46	2.32	1.53	1.86
Ethylbenzene	2.20	3.44	1.67	2.23

Table 4-9. Composite SI VOC profile percentages with all compounds

Specie ID	CAS Number	Compound	E0 % 4 stroke	E0 % 2 stroke	E10 % 4 stroke	E10 % 2 stroke
1	135-98-8	(1-methylpropyl)benzene	0.00E+00	3.41E-03	5.38E-02	3.31E-03
9	4259-00-1	1,1,2-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	3073-66-3	1,1,3-TRIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13	4516-69-2	1,1,3-TRIMETHYLCYCLOPENTANE	2.84E-02	0.00E+00	3.11E-02	0.00E+00
19	590-66-9	1,1-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	1638-26-2	1,1-DIMETHYLCYCLOPENTANE	3.99E-03	8.79E-03	3.81E-03	2.99E-03
21	16747-50-5	1,1-Methylethylcyclopentane	7.32E-04	1.90E-02	1.90E-03	1.94E-02
36	135-01-3	1,2 DIETHYLBENZENE	3.39E-02	9.03E-02	0.00E+00	7.78E-02
22	488-23-3	1,2,3,4-TETRAMETHYLBENZENE	1.87E-03	7.15E-02	5.00E-02	7.12E-02
23	527-53-7	1,2,3,5-TETRAMETHYLBENZENE	1.07E-01	1.32E-02	6.05E-02	1.19E-02
25	526-73-8	1,2,3-TRIMETHYLBENZENE	2.75E-01	2.13E-02	1.98E-01	6.57E-02
28	95-93-2	1,2,4,5-TETRAMETHYLBENZENE	1.77E-02	1.28E-01	1.07E-02	1.44E-01
29	877-44-1	1,2,4-TRIETHYLBENZENE	8.47E-04	2.37E-02	0.00E+00	2.07E-02
30	95-63-6	1,2,4-TRIMETHYLBENZENE	1.71E+00	2.14E+00	1.58E+00	2.05E+00
37	933-98-2	1,2-dimethyl-3-ethylbenzene	0.00E+00	5.79E-03	0.00E+00	4.18E-03
39	934-80-5	1,2-DIMETHYL-4-ETHYLBENZENE	1.53E-01	3.67E-02	1.16E-01	2.81E-02
42	463-49-0	1,2-PROPADIENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	102-25-0	1,3,5-TRIETHYLBENZENE	0.00E+00	2.47E-02	0.00E+00	1.88E-02

44	108-67-8	1,3,5-TRIMETHYLBENZENE	5.36E-01	7.68E-01	6.95E-01	7.37E-01
55	934-74-7	1,3,-DIMETHYL-5-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
46	106-99-0	1,3-BUTADIENE	1.28E+00	2.14E-01	1.24E+00	2.72E-01
51	141-93-5	1,3-DIETHYLBENZENE	7.93E-02	1.77E-01	7.83E-02	1.73E-01
52	2870-04-4	1,3-DIMETHYL-2-ETHYLBENZENE	7.72E-02	1.78E-02	3.04E-02	1.42E-02
53	874-41-9	1,3-DIMETHYL-4-ETHYLBENZENE	4.13E-02	8.14E-02	1.14E-01	7.96E-03
54	4706-89-2	1,3-dimethyl-4-isopropylbenzene	3.13E-02	0.00E+00	7.21E-02	0.00E+00
59	105-05-5	1,4-DIETHYLBENZENE	2.36E-02	4.19E-01	0.00E+00	4.00E-01
60	1758-88-9	1,4-DIMETHYL-2-ETHYLBENZENE	6.99E-02	2.55E-01	7.94E-02	2.45E-01
64	106-98-9	1-BUTENE	4.43E-01	1.20E-01	5.27E-01	1.30E-01
65	107-00-6	1-butyne	0.00E+00	0.00E+00	0.00E+00	0.00E+00
357	15890-40-1	1-CIS,2-TRANS,3-TRIMETHYLCYCLOPENTANE	4.34E-02	1.48E-01	6.27E-02	1.60E-01
996	872-05-9	1-DECENE	0.00E+00	1.55E-02	9.41E-02	1.39E-02
75	637-92-3	1-ethyltertbutylether	0.00E+00	0.00E+00	0.00E+00	0.00E+00
76	592-76-7	1-HEPTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
78	592-41-6	1-HEXENE	4.08E-02	9.50E-02	1.18E-01	1.11E-01
80	611-14-3	1-METHYL-2-ETHYLBENZENE	4.15E-01	6.28E-01	4.09E-01	5.05E-01
81	527-84-4	1-METHYL-2-ISOPROPYLBENZENE	2.17E-01	6.66E-02	3.24E-01	5.19E-02
84	1074-17-5	1-METHYL-2-N-PROPYLBENZENE	4.63E-02	3.73E-02	1.12E-01	2.88E-02
89	620-14-4	1-METHYL-3-ETHYLBENZENE	1.25E+00	1.85E+00	1.11E+00	1.57E+00
90	535-77-3	1-METHYL-3-ISOPROPYLBENZENE	3.46E-01	4.03E-02	2.73E-01	2.71E-02
92	1074-43-7	1-METHYL-3-N-PROPYLBENZENE	1.56E-01	2.25E-01	2.82E-01	1.88E-01
94	622-96-8	1-METHYL-4-ETHYLBENZENE	5.13E-01	7.87E-01	3.64E-01	6.51E-01
97	99-87-6	1-METHYL-4-ISOPROPYLBENZENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	1074-55-1	1-METHYL-4-N-PROPYLBENZENE	1.40E-01	4.47E-02	7.16E-02	2.39E-02
103	693-89-0	1-METHYLCYCLOPENTENE	1.76E-02	1.14E-01	7.73E-02	1.70E-01
106	124-11-8	1-NONENE	1.34E-01	1.78E-01	2.94E-02	7.05E-02
107	111-66-0	1-OCTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
108	109-67-1	1-pentene	0.00E+00	1.75E-01	0.00E+00	2.28E-01
607	71-23-8	1-Propanol	1.17E-01	0.00E+00	7.27E-02	0.00E+00
730	15890-40-1	1-TRANS-2-CIS-3-TRIMETHYLCYCLOPENTANE	8.82E-03	6.46E-02	2.15E-02	7.98E-02
1540	2815-58-9	1-TRANS-2-CIS-4-TRIMETHYLCYCLOPENTANE	0.00E+00	7.61E-02	0.00E+00	7.06E-02
112	464-06-2	2,2,3-TRIMETHYLBUTANE	3.01E-02	5.95E-02	5.49E-02	7.01E-02
113	564-02-3	2,2,3-TRIMETHYLPENTANE	5.17E-01	9.61E-01	3.64E-01	1.07E+00
117	16747-26-5	2,2,4-trimethylhexane	5.29E-03	2.63E-02	0.00E+00	1.98E-02
118	540-84-1	2,2,4-TRIMETHYLPENTANE	4.61E+00	8.11E+00	5.72E+00	1.30E+01
121	3522-94-9	2,2,5-TRIMETHYLHEXANE	3.78E-01	5.90E-01	6.16E-02	4.18E-02
122	75-83-2	2,2-DIMETHYLBUTANE	3.61E-02	9.26E-02	5.02E-02	7.14E-02
123	1071-26-7	2,2-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
124	590-73-8	2,2-DIMETHYLHEXANE	5.44E-03	1.01E-01	9.04E-03	9.03E-02
125	15869-87-1	2,2-DIMETHYLOCTANE	6.82E-02	9.52E-02	3.41E-02	5.68E-02
126	590-35-2	2,2-DIMETHYLPENTANE	7.50E-02	4.30E-01	2.62E-01	6.25E-01
127	463-82-1	2,2-DIMETHYLPROPANE (NEOPENTANE)	0.00E+00	8.74E-02	0.00E+00	7.21E-02
128	560-21-4	2,3,3-TRIMETHYLPENTANE	7.43E-01	1.48E+00	1.31E-01	2.13E-01
129	921-47-1	2,3,4-TRIMETHYLHEXANE	0.00E+00	2.03E-02	0.00E+00	2.09E-02
130	565-75-3	2,3,4-TRIMETHYLPENTANE	1.14E+00	2.46E+00	2.65E-01	6.80E-01
132	1069-53-0	2,3,5-TRIMETHYLHEXANE	5.92E-02	9.31E-02	1.39E-02	3.83E-02
135	10574-37-5	2,3-DIMETHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
136	79-29-8	2,3-DIMETHYLBUTANE	4.76E-01	7.50E-01	2.37E-01	5.52E-01
137	3074-71-3	2,3-DIMETHYLHEPTANE	0.00E+00	1.85E-02	0.00E+00	2.50E-02
138	584-94-1	2,3-DIMETHYLHEXANE	1.70E-01	0.00E+00	1.40E-02	1.32E-01
140	565-59-3	2,3-DIMETHYLPENTANE	2.28E+00	6.31E-01	1.72E+00	1.49E-03

141	107-39-1	2,4,4-TRIMETHYL-1-PENTENE	8.70E-03	9.19E-02	7.99E-02	1.09E-01
142	107-40-4	2,4,4-TRIMETHYL-2-PENTENE	0.00E+00	1.19E-02	6.27E-02	1.88E-02
143	16747-30-1	2,4,4-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
148	2213-23-2	2,4-DIMETHYLHEPTANE	5.42E-02	8.05E-02	2.81E-02	6.13E-02
149	589-43-5	2,4-DIMETHYLHEXANE	5.85E-01	1.32E+00	4.26E-01	1.17E+00
151	4032-94-4	2,4-DIMETHYLOCTANE	9.48E-03	6.06E-02	3.94E-02	6.85E-02
152	108-08-7	2,4-DIMETHYLPENTANE	1.34E+00	1.44E+00	4.00E-01	9.68E-01
155	2216-30-0	2,5-DIMETHYLHEPTANE	6.60E-02	9.15E-02	3.93E-02	6.90E-02
156	592-13-2	2,5-dimethylhexane	0.00E+00	2.45E-03	0.00E+00	0.00E+00
160	1072-05-5	2,6-DIMETHYLHEPTANE	0.00E+00	4.56E-03	0.00E+00	6.88E-03
170	503-17-3	2-butyne	0.00E+00	0.00E+00	0.00E+00	0.00E+00
511	78-79-5	2-METHYL-1,3-BUTADIENE	2.33E-01	1.12E-01	3.19E-01	1.47E-01
181	563-46-2	2-methyl-1-butene	0.00E+00	2.97E-01	0.00E+00	4.52E-01
2185	6094-02-6	2-METHYL-1-HEXENE	0.00E+00	2.72E-02	5.24E-03	3.04E-02
184	763-29-1	2-METHYL-1-PENTENE	4.08E-02	1.06E-01	1.18E-01	1.31E-01
185	513-35-9	2-METHYL-2-BUTENE	2.45E-01	5.99E-01	2.92E-01	7.74E-01
186	2738-19-4	2-methyl-2-hexene	0.00E+00	1.08E-01	1.58E-02	1.35E-01
187	625-27-4	2-METHYL-2-PENTENE	4.53E-02	1.34E-01	8.68E-02	1.88E-01
508	78-78-4	2-METHYLBUTANE (ISOPENTANE)	2.73E+00	1.05E+01	1.79E+00	6.28E+00
2568	03968-85-2	2-METHYLBUTYLBENZENE (sec AMYLBENZENE)	1.44E-02	1.58E-01	0.00E+00	1.58E-01
193	592-27-8	2-METHYLHEPTANE	2.66E-01	7.91E-01	2.51E-01	5.62E-01
194	591-76-4	2-METHYLHEXANE	0.00E+00	2.66E+00	0.00E+00	5.14E+00
198	3221-61-2	2-METHYLOCTANE	2.24E-01	6.29E-01	1.99E-01	4.80E-01
199	107-83-5	2-METHYLPENTANE	4.07E-01	1.77E+00	9.50E-01	2.38E+00
491	75-28-5	2-METHYLPROPANE (ISOBUTANE)	1.72E-01	2.29E-01	3.85E-02	1.62E-02
497	115-11-7	2-METHYLPROPENE (ISOBUTYLENE)	3.28E+00	7.64E-01	3.74E+00	1.04E+00
513	67-63-0	2-Propanol	1.76E-02	1.71E-02	5.81E-03	0.00E+00
203	558-37-2	3,3-DIMETHYL-1-BUTENE	2.22E-02	9.98E-03	4.66E-02	1.02E-02
205	4032-86-4	3,3-DIMETHYLHEPTANE	0.00E+00	3.24E-02	0.00E+00	3.83E-02
206	563-16-6	3,3-DIMETHYLHEXANE	3.10E-02	8.73E-02	5.36E-02	8.27E-02
208	562-49-2	3,3-DIMETHYLPENTANE	3.20E-02	9.83E-02	8.52E-03	4.17E-02
209	7385-78-6	3,4-DIMETHYL-1-PENTENE	1.01E-02	1.73E-02	1.56E-02	2.18E-02
211	922-28-1	3,4-DIMETHYLHEPTANE	0.00E+00	4.35E-02	0.00E+00	2.96E-02
212	583-48-2	3,4-DIMETHYLHEXANE	4.71E-02	8.84E-02	1.13E-02	7.29E-02
215	926-82-9	3,5-DIMETHYLHEPTANE	6.61E-02	9.15E-02	3.93E-02	6.90E-02
221	816-79-5	3-ethyl-2-pentene	0.00E+00	1.03E-02	0.00E+00	1.24E-02
226	619-99-8	3-ETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
229	617-78-7	3-ETHYLPENTANE	3.23E-02	2.19E-01	1.23E-01	3.35E-01
230	563-45-1	3-METHYL-1-BUTENE	5.11E-02	2.03E-01	9.65E-02	1.31E-01
231	3404-61-3	3-methyl-1-hexene	0.00E+00	1.96E-02	0.00E+00	2.03E-02
232	760-20-3	3-METHYL-1-PENTENE	3.78E-02	8.18E-02	5.11E-02	9.03E-02
233	1067-08-9	3-Methyl-3-ethyl-pentane	4.71E-02	8.84E-02	1.13E-02	7.29E-02
236	922-62-3	3-METHYL-CIS-2-PENTENE	3.95E-02	1.60E-01	8.21E-02	2.40E-01
242	1120-62-3	3-METHYLCYCLOPENTENE	4.18E-03	3.06E-03	2.24E-02	3.40E-03
244	589-81-1	3-METHYLHEPTANE	3.29E-01	1.23E+00	2.81E-01	7.42E-01
245	589-34-4	3-METHYLHEXANE	2.35E-01	1.61E+00	4.95E-01	1.38E+00
247	2216-33-3	3-METHYLOCTANE	1.40E-01	4.45E-01	1.15E-01	3.18E-01
248	96-14-0	3-METHYLPENTANE	2.47E-01	1.09E+00	6.51E-01	1.58E+00
239	616-12-6	3-METHYL-TRANS-2-PENTENE	4.54E-02	2.01E-01	1.12E-01	2.80E-01
240	3899-36-3	3-methyl-trans-3-hexene	0.00E+00	0.00E+00	0.00E+00	0.00E+00
253	1068-19-5	4,4-DIMETHYLHEPTANE	5.18E-03	9.77E-02	1.13E-02	7.37E-02

1471	2216-32-2	4-ETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
258	691-37-2	4-METHYL-1-PENTENE	0.00E+00	1.23E-03	0.00E+00	2.00E-02
260	691-38-3	4-METHYL-CIS-2-PENTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
264	589-53-7	4-METHYLHEPTANE	7.24E-02	7.48E-01	4.15E-02	1.80E-01
267	2216-34-4	4-methyloctane	0.00E+00	0.00E+00	0.00E+00	0.00E+00
262	674-76-0	4-METHYL-TRANS-2-PENTENE	6.44E-03	6.68E-02	0.00E+00	8.35E-02
279	75-07-0	Acetaldehyde	4.25E-01	1.03E-01	8.97E-01	3.36E-01
282	74-86-2	ACETYLENE	1.66E+01	3.17E+00	1.59E+01	2.75E+00
283	107-02-8	Acrolein	3.71E-02	3.12E-02	4.49E-02	4.43E-02
301	100-52-7	Benzaldehyde	5.24E-01	1.08E-01	2.59E-01	6.66E-02
302	71-43-2	BENZENE	6.94E+00	1.39E+00	4.59E+00	1.26E+00
592	106-97-8	BUTANE	7.65E-01	1.72E+00	6.09E-01	1.20E+00
351	2207-01-4	CIS-1,2-DIMETHYLCYCLOHEXANE	4.37E-02	1.13E-01	4.37E-02	1.02E-01
360	1192-18-3	CIS-1,2-DIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
352	638-04-0	Cis-1,3-dimethylcyclohexane	0.00E+00	0.00E+00	0.00E+00	0.00E+00
353	2532-58-3	CIS-1,3-DIMETHYLCYCLOPENTANE	2.61E-02	7.00E-02	1.07E-01	1.96E-02
354	624-29-3	Cis-1,4-Dimethylcyclohexane	1.42E-03	2.65E-02	8.64E-03	2.77E-02
362	930-89-2	Cis-1-ethyl-2-methylcyclopentane	1.22E-02	8.66E-02	2.02E-02	6.71E-02
364	2613-66-3	CIS-1-METHYL-3-ETHYLCYCLOPENTANE	2.20E-02	4.80E-02	4.86E-02	5.97E-02
367	590-18-1	CIS-2-BUTENE	2.21E-01	7.86E-02	2.37E-01	1.06E-01
368	6443-92-1	CIS-2-HEPTENE	1.98E-02	5.24E-02	2.67E-02	5.82E-02
369	7688-21-3	CIS-2-HEXENE	2.94E-02	7.79E-02	2.52E-02	9.75E-02
370	7642-04-8	CIS-2-OCTENE	0.00E+00	7.71E-02	0.00E+00	1.29E-02
371	627-20-3	CIS-2-PENTENE	1.24E-01	2.20E-01	1.74E-01	2.87E-01
2616	7642-10-6	CIS-3-HEPTENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
372	7642-09-3	CIS-3-HEXENE	6.63E-03	9.40E-02	3.38E-02	1.18E-01
373	20237-46-1	CIS-3-NONENE	0.00E+00	6.86E-03	0.00E+00	6.37E-03
382	4170-30-3	Crotonaldehyde	3.67E-02	1.96E-02	2.96E-02	2.41E-02
385	110-82-7	CYCLOHEXANE	6.54E-02	5.38E-02	6.40E-01	7.75E-02
388	110-83-8	CYCLOHEXENE	1.43E-01	2.83E-02	5.54E-02	3.80E-02
48	542-92-7	CYCLOPENTADIENE	4.27E-01	1.20E-01	4.77E-01	1.24E-01
390	287-92-3	CYCLOPENTANE	4.50E-02	7.61E-02	6.80E-02	1.06E-01
391	142-29-0	CYCLOPENTENE	3.61E-02	9.25E-02	8.73E-02	1.30E-01
598	124-18-5	DECANE	6.56E-02	7.76E-02	4.72E-02	5.99E-02
2735	108-20-3	DI-ISOPROPYL ETHER	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1712	5779-94-2	Dimethylbenzaldehyde	1.08E-01	2.03E-02	5.23E-02	2.42E-02
599	112-40-3	DODECANE	2.32E-02	8.21E-02	1.12E-02	5.34E-02
442	64-17-5	Ethanol	1.72E-01	5.79E-02	3.03E+00	7.81E+00
449	100-41-4	ETHYLBENZENE	2.20E+00	3.44E+00	1.67E+00	2.23E+00
450	1678-91-7	ETHYLCYCLOHEXANE	2.72E-02	1.78E-01	2.98E-02	1.09E-01
451	1640-89-7	ETHYLCYCLOPENTANE	2.43E-03	0.00E+00	1.41E-02	0.00E+00
452	74-85-1	ETHYLENE	1.10E+01	1.83E+00	1.23E+01	1.99E+00
465	50-00-0	Formaldehyde	1.98E+00	3.68E-01	1.76E+00	4.98E-01
600	142-82-5	HEPTANE	3.18E-01	1.18E+00	2.70E-01	6.31E-01
840	66-25-1	Hexanaldehyde	1.19E-03	1.93E-03	5.32E-03	1.95E-03
601	110-54-3	HEXANE	2.33E-01	7.72E-01	5.20E-01	7.15E-01
602	1077-16-3	HEXYLBENZENE	0.00E+00	1.82E-02	0.00E+00	2.90E-02
485	496-11-7	INDAN	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	538-93-2	ISOBUTYLBENZENE	6.19E-02	7.32E-02	4.46E-02	5.65E-02
2119	78-84-2	ISOBUTYRALDEHYDE,	1.68E-02	9.85E-03	2.37E-02	1.02E-02
514	98-82-8	ISOPROPYLBENZENE (CUMENE)	1.18E-01	1.11E-01	4.69E-02	6.35E-02
2560	3875-51-2	ISOPROPYLCYCLOPENTANE	6.02E-03	1.16E-02	7.23E-03	3.45E-02

517	590-86-3	Isovaleraldehyde	6.12E-02	1.42E-02	5.26E-02	1.90E-02
522	1330-20-7	m-& p-XYLENE	4.40E+00	6.44E+00	5.46E+00	5.39E+00
2164	1334-78-7	m/p-Tolualdehyde	3.27E-01	4.65E-02	2.35E-01	7.74E-02
536	78-93-3	MEK	1.69E-02	9.85E-03	2.37E-02	1.02E-02
531	67-56-1	Methanol	2.05E-01	7.84E-02	2.09E-01	1.32E-01
548	1634-04-4	Methyl t-butyl ether (MTBE)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
550	108-87-2	METHYLCYCLOHEXANE	1.02E-01	4.40E-01	2.79E-01	6.44E-01
551	96-37-7	METHYLCYCLOPENTANE	7.35E-02	4.22E-01	2.57E-01	6.13E-01
611	91-20-3	NAPHTHALENE	4.15E-02	5.96E-02	8.86E-02	4.68E-02
595	71-36-3	N-butyl alcohol	6.80E-02	0.00E+00	3.94E-02	0.00E+00
596	104-51-8	n-Butylbenzene	1.40E-01	3.03E-02	7.16E-02	2.39E-02
603	111-84-2	NONANE	2.08E-01	3.49E-01	7.42E-02	1.59E-01
606	538-68-1	N-PENT-BENZENE	3.23E-02	7.90E-02	3.38E-02	9.19E-02
608	103-65-1	n-PROPYLBENZENE	3.39E-01	6.85E-01	2.91E-01	4.86E-01
604	00111-65-9	OCTANE	2.71E-01	4.59E-01	1.75E-01	3.08E-01
1467	529-20-4	o-Tolualdehyde	8.48E-02	4.58E-02	4.04E-02	1.82E-02
620	95-47-6	o-XYLENE	1.46E+00	2.32E+00	1.53E+00	1.86E+00
605	109-66-0	PENTANE	4.11E-01	8.63E-01	3.90E-01	8.87E-01
671	74-98-6	PROPANE	3.30E-01	4.61E-02	8.69E-02	3.12E-02
673	123-38-6	Propionaldehyde	4.94E-02	5.06E-02	4.11E-02	5.23E-02
677	2040-96-2	Propylcyclopentane	0.00E+00	3.06E-03	0.00E+00	6.88E-03
678	115-07-1	PROPYLENE	6.51E+00	1.17E+00	6.44E+00	1.30E+00
109	74-99-7	PROPYNE	4.52E-03	2.31E-02	0.00E+00	1.94E-02
698	100-42-5	STYRENE	9.76E-01	2.23E-01	7.15E-01	1.77E-01
701	994-05-8	T-amylmethylether	0.00E+00	0.00E+00	0.00E+00	0.00E+00
86	1074-92-6	TERT-1-BUT-2-METHYLBENZENE	4.44E-03	1.32E-01	3.64E-02	1.61E-01
63	98-19-1	TERT-1-BUT-3,5-DIMETHYLBENZENE	2.66E-03	1.19E-01	8.90E-04	1.39E-01
2329	7364-19-4	TERT-1-BUTYL-4-ETHYLBENZENE	0.00E+00	5.73E-02	2.85E-02	6.18E-02
703	98-06-6	TERT-BUTYLBENZENE	0.00E+00	3.05E-02	0.00E+00	3.22E-02
717	108-88-3	TOLUENE	8.64E+00	8.64E+00	7.77E+00	7.77E+00
724	6876-23-9	TRANS-1,2-DIMETHYLCYCLOHEXANE	7.25E-03	3.92E-01	2.67E-02	1.77E-01
725	822-50-4	TRANS-1,2-DIMETHYLCYCLOPENTANE	3.52E-02	1.03E-01	3.51E-02	1.01E-01
726	2207-03-6	TRANS-1,3-DIMETHYLCYCLOHEXANE	1.42E-03	3.14E-02	8.64E-03	3.09E-02
727	1759-58-6	TRANS-1,3-DIMETHYLCYCLOPENTANE	4.02E-03	2.32E-01	0.00E+00	3.60E-01
729	2207-04-7	TRANS-1,4-DIMETHYLCYCLOHEXANE	0.00E+00	9.47E-03	1.18E-02	2.45E-02
1586	930-90-5	Trans-1-ethyl-2-methyl-cyclopentane	1.99E-03	9.29E-02	3.28E-02	1.14E-01
736	2613-65-2	TRANS-1-METHYL-3-ETHYLCYCLOPENTANE	0.00E+00	1.08E-01	3.10E-02	1.40E-01
737	624-64-6	TRANS-2-BUTENE	3.93E-01	2.08E-01	3.08E-01	2.34E-01
739	14686-13-6	TRANS-2-HEPTENE	1.50E-02	6.09E-02	3.01E-02	6.89E-02
740	4050-45-7	TRANS-2-HEXENE	1.56E-02	1.43E-01	5.20E-02	1.82E-01
2244	6434-78-2	TRANS-2-NONENE	0.00E+00	1.28E-02	0.00E+00	8.18E-03
741	13389-42-9	TRANS-2-OCTENE	7.72E-03	8.42E-02	5.05E-02	1.14E-01
742	646-04-8	TRANS-2-PENTENE	4.11E-02	3.83E-01	1.10E-01	5.02E-01
743	14686-14-7	TRANS-3-HEPTENE	9.04E-04	8.81E-02	3.13E-02	1.12E-01
744	13269-52-8	TRANS-3-HEXENE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
745	20063-92-7	TRANS-3-NONENE	0.00E+00	4.59E-02	1.41E-02	5.24E-02
746	14850-23-8	Trans-4-octene	0.00E+00	5.59E-02	0.00E+00	4.67E-02
610	1120-21-4	UNDECANE	3.85E-02	1.17E-01	3.94E-02	1.11E-01
1989		UNIDENTIFIED C5 OLEFINS	0.00E+00	1.38E-02	0.00E+00	8.96E-03
1999		UNIDENTIFIED C6	1.62E-01	7.41E-02	1.91E-01	7.17E-02
2005		UNIDENTIFIED C7	1.26E-01	7.69E-01	1.21E-01	2.77E-01
2011		UNIDENTIFIED C8	2.48E-03	1.68E-01	1.03E-02	1.20E-01

327		UNIDENTIFIED C9-C12+	1.31E+00	3.94E+00	1.88E+00	3.64E+00
845	110-62-3	Valeraldehyde	1.62E-02	4.58E-03	5.35E-03	4.83E-03

Table 4-10. Composite Transient Cycle CI VOC Profile Percentages by Compound Class

Compound	Pre-Tier 1	Tier 1	Tier 2
Paraffins	15.26	11.16	7.54
Aromatics	12.23	7.13	10.79
Olefins	27.56	33.16	24.04
Aldehydes/Ketones	39.22	47.00	51.08
Oxygenates	0.00	0.00	0.00
Unknowns	5.73	1.54	6.55

Table 4-11. Composite Transient Cycle CI VOC Profile Percentages of Selected Compounds

Compound	Pre-Tier 1	Tier 1	Tier 2
Formaldehyde	20.67	22.27	29.19
Acetaldehyde	7.46	7.83	10.41
Ethylene	17.36	20.74	20.34
Propylene	0.00	4.10	0.00
2,2,4-Trimethylpentane	0.81	0.71	0.78
2-Methylbutane	0.00	0.53	0.00
Toluene	1.22	2.15	3.78
m-& p-Xylene	1.53	1.20	1.16
o-Xylene	0.73	0.44	0.00
Ethylbenzene	0.94	0.38	0.44

Table 4-12. Composite Transient Cycle CI VOC Exhaust Speciation Profiles Displayed as Weight Percentages of Total VOCs

Specie ID	**CAS Number**	**COMPOUND**	**Pre-Tier 1**	**Tier 1**	**Tier 2**
1	135-98-8	(1-methylpropyl)benzene	0.00E+00	0.00E+00	0.00E+00
9	4259-00-1	1,1,2-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
12	3073-66-3	1,1,3-TRIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
13	4516-69-2	1,1,3-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
19	590-66-9	1,1-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
20	1638-26-2	1,1-DIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
21	16747-50-5	1,1-Methylethylcyclopentane	0.00E+00	0.00E+00	0.00E+00
36	135-01-3	1,2 DIETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
22	488-23-3	1,2,3,4-TETRAMETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
23	527-53-7	1,2,3,5-TETRAMETHYLBENZENE	1.15E-01	3.11E-02	0.00E+00
25	526-73-8	1,2,3-TRIMETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
28	95-93-2	1,2,4,5-TETRAMETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00

29	877-44-1	1,2,4-TRIETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
30	95-63-6	1,2,4-TRIMETHYLBENZENE	3.95E-01	2.47E-02	0.00E+00
37	933-98-2	1,2-DIMETHYL-3-ETHYLBENZENE	0.00E+00	1.74E-02	0.00E+00
39	934-80-5	1,2-DIMETHYL-4-ETHYLBENZENE	4.06E-02	7.23E-02	0.00E+00
42	463-49-0	1,2-PROPADIENE	0.00E+00	0.00E+00	0.00E+00
43	102-25-0	1,3,5-TRIETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
44	108-67-8	1,3,5-TRIMETHYLBENZENE	4.59E-01	0.00E+00	0.00E+00
55	934-74-7	1,3,-DIMETHYL-5-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
46	106-99-0	1,3-BUTADIENE	1.86E-01	1.86E-01	1.86E-01
51	141-93-5	1,3-DIETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
52	2870-04-4	1,3-DIMETHYL-2-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
53	874-41-9	1,3-DIMETHYL-4-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
54	4706-89-2	1,3-dimethyl-4-isopropylbenzene	0.00E+00	0.00E+00	0.00E+00
59	105-05-5	1,4-DIETHYLBENZENE	5.04E-01	2.33E-02	0.00E+00
60	1758-88-9	1,4-DIMETHYL-2-ETHYLBENZENE	9.66E-02	3.36E-03	0.00E+00
64	106-98-9	1-BUTENE	0.00E+00	3.05E-01	0.00E+00
65	107-00-6	1-BUTYNE	0.00E+00	0.00E+00	0.00E+00
357	15890-40-1	1-CIS,2-TRANS,3-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
996	872-05-9	1-DECENE	0.00E+00	0.00E+00	0.00E+00
75	637-92-3	1-ethyltertbutylether	0.00E+00	0.00E+00	0.00E+00
76	592-76-7	1-HEPTENE	0.00E+00	0.00E+00	0.00E+00
78	592-41-6	1-HEXENE	6.66E-01	4.31E-01	1.48E-01
80	611-14-3	1-METHYL-2-ETHYLBENZENE	2.90E-01	3.37E-03	0.00E+00
81	527-84-4	1-METHYL-2-ISOPROPYLBENZENE	3.96E-01	1.11E-01	0.00E+00
84	1074-17-5	1-METHYL-2-N-PROPYLBENZENE	0.00E+00	0.00E+00	0.00E+00
89	620-14-4	1-METHYL-3-ETHYLBENZENE	4.32E-01	1.54E-02	0.00E+00
90	535-77-3	1-METHYL-3-ISOPROPYLBENZENE	0.00E+00	8.13E-02	0.00E+00
92	1074-43-7	1-METHYL-3-N-PROPYLBENZENE	0.00E+00	0.00E+00	0.00E+00
94	622-96-8	1-METHYL-4-ETHYLBENZENE	2.48E-01	0.00E+00	0.00E+00
97	99-87-6	1-METHYL-4-ISOPROPYLBENZENE	0.00E+00	0.00E+00	0.00E+00
100	1074-55-1	1-METHYL-4-N-PROPYLBENZENE	2.62E-01	1.17E-02	0.00E+00
103	693-89-0	1-METHYLCYCLOPENTENE	3.89E-01	0.00E+00	0.00E+00
106	124-11-8	1-NONENE	8.04E-01	9.49E-02	0.00E+00
107	111-66-0	1-OCTENE	0.00E+00	0.00E+00	0.00E+00
108	109-67-1	1-PENTENE	1.33E+00	5.86E-01	2.22E-01
730	15890-40-1	1-TRANS-2-CIS-3-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
1540	2815-58-9	1-TRANS-2-CIS-4-TRIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
112	464-06-2	2,2,3-TRIMETHYLBUTANE	7.36E-01	4.77E-03	0.00E+00
113	564-02-3	2,2,3-TRIMETHYLPENTANE	0.00E+00	2.79E-01	0.00E+00
117	16747-26-5	2,2,4-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
118	540-84-1	2,2,4-TRIMETHYLPENTANE	8.07E-01	7.12E-01	7.83E-01
121	3522-94-9	2,2,5-TRIMETHYLHEXANE	0.00E+00	4.41E-02	0.00E+00
122	75-83-2	2,2-DIMETHYLBUTANE	3.68E-02	1.82E-01	0.00E+00
123	1071-26-7	2,2-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00

124	590-73-8	2,2-DIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
125	15869-87-1	2,2-DIMETHYLOCTANE	4.60E-01	1.76E-02	0.00E+00
126	590-35-2	2,2-DIMETHYLPENTANE	1.91E-02	5.95E-02	6.15E-02
127	463-82-1	2,2-DIMETHYLPROPANE (NEOPENTANE)	0.00E+00	8.75E-02	0.00E+00
128	560-21-4	2,3,3-TRIMETHYLPENTANE	8.10E-02	4.85E-01	4.30E-01
129	921-47-1	2,3,4-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
130	565-75-3	2,3,4-TRIMETHYLPENTANE	2.58E-01	7.42E-02	4.88E-01
132	1069-53-0	2,3,5-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
135	10574-37-5	2,3-DIMETHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
136	79-29-8	2,3-DIMETHYLBUTANE	0.00E+00	1.77E-01	0.00E+00
137	3074-71-3	2,3-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
138	584-94-1	2,3-DIMETHYLHEXANE	0.00E+00	3.63E-01	0.00E+00
140	565-59-3	2,3-DIMETHYLPENTANE	9.07E-02	1.60E-01	3.00E-01
141	107-39-1	2,4,4-TRIMETHYL-1-PENTENE	0.00E+00	0.00E+00	0.00E+00
142	107-40-4	2,4,4-TRIMETHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
143	16747-30-1	2,4,4-TRIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
148	2213-23-2	2,4-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
149	589-43-5	2,4-DIMETHYLHEXANE	5.11E-01	1.30E-01	0.00E+00
151	4032-94-4	2,4-DIMETHYLOCTANE	5.50E-01	5.52E-02	0.00E+00
152	108-08-7	2,4-DIMETHYLPENTANE	1.94E-01	5.06E-01	4.08E-01
155	2216-30-0	2,5-DIMETHYLHEPTANE	2.27E-01	3.78E-02	0.00E+00
156	592-13-2	2,5-DIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
160	1072-05-5	2,6-DIMETHYLHEPTANE	5.62E-01	1.83E-01	1.11E-01
170	503-17-3	2-BUTYNE	0.00E+00	0.00E+00	0.00E+00
511	78-79-5	2-METHYL-1,3-BUTADIENE	9.85E-02	3.59E-01	0.00E+00
181	563-46-2	2-METHYL-1-BUTENE	2.74E-01	1.87E-01	5.92E-01
2185	6094-02-6	2-METHYL-1-HEXENE	0.00E+00	0.00E+00	0.00E+00
184	763-29-1	2-METHYL-1-PENTENE	6.66E-01	4.31E-01	1.48E-01
185	513-35-9	2-METHYL-2-BUTENE	0.00E+00	1.09E-01	2.96E-01
186	2738-19-4	2-METHYL-2-HEXENE	0.00E+00	0.00E+00	0.00E+00
187	625-27-4	2-METHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
508	78-78-4	2-METHYLBUTANE (ISOPENTANE)	0.00E+00	5.29E-01	0.00E+00
2568	03968-85-2	2-METHYLBUTYLBENZENE (sec AMYLBENZENE)	0.00E+00	0.00E+00	0.00E+00
193	592-27-8	2-METHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
194	591-76-4	2-METHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
198	3221-61-2	2-METHYLOCTANE	1.15E+00	1.98E-01	0.00E+00
199	107-83-5	2-METHYLPENTANE	1.54E-01	3.19E-01	2.19E-01
491	75-28-5	2-METHYLPROPANE (ISOBUTANE)	0.00E+00	5.45E-01	6.57E-01
497	115-11-7	2-METHYLPROPENE (ISOBUTYLENE)	3.54E-01	7.71E-01	0.00E+00
203	558-37-2	3,3-DIMETHYL-1-BUTENE	0.00E+00	0.00E+00	0.00E+00
205	4032-86-4	3,3-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
206	563-16-6	3,3-DIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
208	562-49-2	3,3-DIMETHYLPENTANE	0.00E+00	0.00E+00	0.00E+00
209	7385-78-6	3,4-DIMETHYL-1-PENTENE	0.00E+00	1.48E-02	0.00E+00

211	922-28-1	3,4-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
212	583-48-2	3,4-DIMETHYLHEXANE	0.00E+00	0.00E+00	0.00E+00
215	926-82-9	3,5-DIMETHYLHEPTANE	2.27E-01	3.78E-02	0.00E+00
221	816-79-5	3-ETHYL-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
226	619-99-8	3-ETHYLHEXANE	1.14E-01	2.53E-02	0.00E+00
229	617-78-7	3-ETHYLPENTANE	0.00E+00	0.00E+00	0.00E+00
230	563-45-1	3-METHYL-1-BUTENE	0.00E+00	0.00E+00	0.00E+00
231	3404-61-3	3-METHYL-1-HEXENE	0.00E+00	0.00E+00	0.00E+00
232	760-20-3	3-METHYL-1-PENTENE	0.00E+00	0.00E+00	0.00E+00
233	1067-08-9	3-Methyl-3-ethyl-pentane	0.00E+00	0.00E+00	0.00E+00
236	922-62-3	3-METHYL-CIS-2-PENTENE	0.00E+00	1.58E-02	0.00E+00
242	1120-62-3	3-METHYLCYCLOPENTENE	0.00E+00	0.00E+00	0.00E+00
244	589-81-1	3-METHYLHEPTANE	0.00E+00	2.77E-02	1.92E-01
245	589-34-4	3-METHYLHEXANE	1.01E-01	9.78E-02	0.00E+00
247	2216-33-3	3-METHYLOCTANE	6.20E-01	7.34E-02	2.22E-01
248	96-14-0	3-METHYLPENTANE	5.69E-01	7.72E-01	3.71E-02
239	616-12-6	3-METHYL-TRANS-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
240	3899-36-3	3-METHYL-TRANS-3-HEXENE	0.00E+00	0.00E+00	0.00E+00
253	1068-19-5	4,4-DIMETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
1471	2216-32-2	4-ETHYLHEPTANE	0.00E+00	0.00E+00	0.00E+00
258	691-37-2	4-METHYL-1-PENTENE	2.71E-01	5.18E-02	4.07E-01
260	691-38-3	4-METHYL-CIS-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
264	589-53-7	4-METHYLHEPTANE	3.24E-01	2.76E-02	0.00E+00
267	2216-34-4	4-METHYLOCTANE	0.00E+00	0.00E+00	0.00E+00
262	674-76-0	4-METHYL-TRANS-2-PENTENE	0.00E+00	0.00E+00	0.00E+00
279	75-07-0	ACETALDEHYDE	7.46E+00	7.83E+00	1.04E+01
282	74-86-2	ACETYLENE	3.04E+00	3.78E+00	1.15E+00
283	107-02-8	ACROLEIN	3.02E+00	1.60E+00	1.87E+00
301	100-52-7	BENZALDEHYDE	3.56E-01	9.84E-01	7.21E-01
302	71-43-2	BENZENE	1.96E+00	2.25E+00	5.41E+00
592	106-97-8	BUTANE	3.56E-01	1.09E+00	5.47E-01
351	2207-01-4	CIS-1,2-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
360	1192-18-3	CIS-1,2-DIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
352	638-04-0	CIS-1,3-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
353	2532-58-3	CIS-1,3-DIMETHYLCYCLOPENTANE	2.36E-01	3.64E-02	0.00E+00
354	624-29-3	Cis-1,4-Dimethylcyclohexane	0.00E+00	0.00E+00	0.00E+00
362	930-89-2	Cis-1-ethyl-2-methylcyclopentane	3.68E-02	0.00E+00	0.00E+00
364	2613-66-3	CIS-1-METHYL-3-ETHYLCYCLOPENTANE	6.38E-01	2.62E-01	0.00E+00
367	590-18-1	CIS-2-BUTENE	0.00E+00	0.00E+00	0.00E+00
368	6443-92-1	CIS-2-HEPTENE	0.00E+00	1.87E-01	0.00E+00
369	7688-21-3	CIS-2-HEXENE	0.00E+00	0.00E+00	0.00E+00
370	7642-04-8	CIS-2-OCTENE	0.00E+00	0.00E+00	0.00E+00
371	627-20-3	CIS-2-PENTENE	0.00E+00	2.58E-02	0.00E+00
2616	7642-10-6	CIS-3-HEPTENE	0.00E+00	0.00E+00	0.00E+00

372	7642-09-3	CIS-3-HEXENE	0.00E+00	2.65E-02	0.00E+00
373	20237-46-1	CIS-3-NONENE	0.00E+00	0.00E+00	0.00E+00
382	4170-30-3	CROTONALDEHYDE	1.98E+00	4.27E+00	3.47E+00
385	110-82-7	CYCLOHEXANE	9.57E-02	0.00E+00	0.00E+00
388	110-83-8	CYCLOHEXENE	4.39E-01	1.21E-01	0.00E+00
48	542-92-7	CYCLOPENTADIENE	0.00E+00	9.20E-03	0.00E+00
390	287-92-3	CYCLOPENTANE	2.09E-01	3.93E-02	0.00E+00
391	142-29-0	CYCLOPENTENE	4.41E-02	3.84E-02	0.00E+00
598	124-18-5	DECANE	1.86E-01	2.70E-02	0.00E+00
2735	108-20-3	DI-ISOPROPYL ETHER	0.00E+00	0.00E+00	0.00E+00
1712	5779-94-2	DIMETHYLBENZALDEHYDE	1.47E-01	3.01E-01	4.28E-01
599	112-40-3	DODECANE	4.58E-01	1.14E-01	0.00E+00
442	64-17-5	ETHANOL	0.00E+00	0.00E+00	0.00E+00
449	100-41-4	ETHYLBENZENE	9.44E-01	3.84E-01	4.38E-01
450	1678-91-7	ETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
451	1640-89-7	ETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
452	74-85-1	ETHYLENE	1.74E+01	2.07E+01	2.03E+01
465	50-00-0	FORMALDEHYDE	2.07E+01	2.23E+01	2.92E+01
600	142-82-5	HEPTANE	2.73E-01	9.71E-02	0.00E+00
840	66-25-1	HEXANALDEHYDE	2.14E-01	2.40E-01	0.00E+00
601	110-54-3	HEXANE	2.30E-01	2.79E-01	0.00E+00
602	1077-16-3	HEXYLBENZENE	0.00E+00	0.00E+00	0.00E+00
485	496-11-7	INDAN	0.00E+00	0.00E+00	0.00E+00
3	538-93-2	ISOBUTYLBENZENE	1.79E-01	2.54E-02	0.00E+00
2119	78-84-2	ISOBUTYRALDEHYDE	6.31E-01	7.96E-01	9.19E-01
514	98-82-8	ISOPROPYLBENZENE (CUMENE)	3.71E-01	7.41E-02	0.00E+00
2560	3875-51-2	ISOPROPYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
517	590-86-3	ISOVALERALDEHYDE	7.01E-01	5.20E-01	0.00E+00
522	1330-20-7	m-& p-XYLENE	1.53E+00	1.20E+00	1.16E+00
2164	1334-78-7	M/P-TOLUALDEHYDE	1.41E+00	1.92E+00	7.52E-01
536	78-93-3	MEK	6.31E-01	8.01E-01	9.19E-01
531	67-56-1	METHANOL	0.00E+00	0.00E+00	0.00E+00
548	1634-04-4	Methyl t-butyl ether	0.00E+00	0.00E+00	0.00E+00
550	108-87-2	METHYLCYCLOHEXANE	3.63E-01	2.74E-01	0.00E+00
551	96-37-7	METHYLCYCLOPENTANE	1.91E-02	5.81E-02	6.15E-02
611	91-20-3	NAPHTHALENE	4.87E-02	6.07E-02	0.00E+00
595	71-36-3	N-butyl alcohol	0.00E+00	0.00E+00	0.00E+00
596	104-51-8	n-Butylbenzene	2.62E-01	1.17E-02	0.00E+00
603	111-84-2	NONANE	2.31E+00	4.37E-01	0.00E+00
606	538-68-1	N-PENT-BENZENE	4.52E-02	0.00E+00	0.00E+00
608	103-65-1	n-PROPYLBENZENE	9.92E-01	2.03E-02	0.00E+00
604	00111-65-9	OCTANE	7.81E-01	3.76E-01	2.80E-01
1467	529-20-4	O-TOLUALDEHYDE	1.12E-01	6.44E-01	0.00E+00
620	95-47-6	o-XYLENE	7.26E-01	4.44E-01	0.00E+00

605	109-66-0	PENTANE	1.23E-01	7.39E-01	1.63E+00
671	74-98-6	PROPANE	6.94E-02	6.30E-01	1.48E-01
673	123-38-6	PROPIONALDEHYDE	1.41E+00	3.86E+00	2.20E+00
677	2040-96-2	Propylcyclopentane	5.62E-01	1.83E-01	1.11E-01
678	115-07-1	PROPYLENE	0.00E+00	4.10E+00	0.00E+00
109	74-99-7	PROPYNE	0.00E+00	0.00E+00	0.00E+00
698	100-42-5	STYRENE	0.00E+00	0.00E+00	0.00E+00
701	994-05-8	T-AMYLMETHYLETHER	0.00E+00	0.00E+00	0.00E+00
86	1074-92-6	TERT-1-BUT-2-METHYLBENZENE	3.65E-01	4.17E-02	0.00E+00
63	98-19-1	TERT-1-BUT-3,5-DIMETHYLBENZENE	3.54E-01	8.22E-02	0.00E+00
2329	7364-19-4	TERT-1-BUTYL-4-ETHYLBENZENE	0.00E+00	0.00E+00	0.00E+00
703	98-06-6	TERT-BUTYLBENZENE	0.00E+00	0.00E+00	0.00E+00
717	108-88-3	TOLUENE	1.22E+00	2.15E+00	3.78E+00
724	6876-23-9	TRANS-1,2-DIMETHYLCYCLOHEXANE	7.36E-02	0.00E+00	0.00E+00
725	822-50-4	TRANS-1,2-DIMETHYLCYCLOPENTANE	0.00E+00	0.00E+00	0.00E+00
726	2207-03-6	TRANS-1,3-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
727	1759-58-6	TRANS-1,3-DIMETHYLCYCLOPENTANE	0.00E+00	9.03E-03	0.00E+00
729	2207-04-7	TRANS-1,4-DIMETHYLCYCLOHEXANE	0.00E+00	0.00E+00	0.00E+00
1586	930-90-5	Trans-1-ethyl-2-methyl-cyclopentane	0.00E+00	0.00E+00	0.00E+00
736	2613-65-2	TRANS-1-METHYL-3-ETHYLCYCLOPENTANE	0.00E+00	3.00E-02	0.00E+00
737	624-64-6	TRANS-2-BUTENE	1.57E+00	5.01E-01	0.00E+00
739	14686-13-6	TRANS-2-HEPTENE	0.00E+00	8.36E-03	0.00E+00
740	4050-45-7	TRANS-2-HEXENE	0.00E+00	6.71E-03	0.00E+00
2244	6434-78-2	TRANS-2-NONENE	0.00E+00	0.00E+00	0.00E+00
741	13389-42-9	TRANS-2-OCTENE	0.00E+00	6.93E-02	0.00E+00
742	646-04-8	TRANS-2-PENTENE	7.74E-02	3.98E-03	5.55E-01
743	14686-14-7	TRANS-3-HEPTENE	0.00E+00	0.00E+00	0.00E+00
744	13269-52-8	TRANS-3-HEXENE	0.00E+00	0.00E+00	0.00E+00
745	20063-92-7	TRANS-3-NONENE	0.00E+00	0.00E+00	0.00E+00
746	14850-23-8	TRANS-4-OCTENE	0.00E+00	9.37E-03	0.00E+00
610	1120-21-4	UNDECANE	4.44E-01	2.69E-01	8.52E-01
1989		UNIDENTIFIED C5 OLEFINS	0.00E+00	1.15E-01	0.00E+00
1999		UNIDENTIFIED C6	4.59E-01	5.91E-01	0.00E+00
2005		UNIDENTIFIED C7	4.77E-02	6.80E-02	0.00E+00
2011		UNIDENTIFIED C8	4.06E-02	2.87E-02	0.00E+00
327		UNIDENTIFIED C9-C12+	5.18E+00	7.38E-01	6.55E+00
845	110-62-3	VALERALDEHYDE	4.66E-01	9.75E-01	1.85E-01

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