PETROLEUM HYDROCARBON GASES CATEGORY ANALYSIS AND HAZARD CHARACTERIZATION

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EXECUTIVE SUMMARY

General Description of the Petroleum Hydrocarbon Gases Category

The 106 Petroleum Hydrocarbon Gas substances in this test plan are primarily produced in petroleum refineries as the light end fractions of numerous distillation and cracking processes, or in gas plants that separate natural gas and natural gas liquids. All petroleum hydrcarbon gases in this category are comprised of predominantly one to four carbon atom hydrocarbons, and may contain asphyxiant gas components such as hydrogen, nitrogen, and carbon dioxide. Several petroleum hydrocarbon gases also contain benzene and/or 1,3-butadiene. These gases exist as substances in closed systems in the refinery, with a few of the gases being sold as finished products, primarily for use as fuels.

The Petroleum Hydrocarbon Gases Category contains 92 petroleum hydrocarbon gas HPV substances, 7 non-HPV substances similar in composition to the HPV gases, and 7 supplementary individual chemicals. The supplemental chemicals are included in this category to characterize the SIDS hazard endpoints for the 99 (both HPV and non-HPV) petroleum hydrocarbon gases. The defining characteristics of Petroleum Hydrocarbon Gases are (1) they contain primarily low molecular weight hydrocarbon molecules which are the dominant hazard in petroleum hydrocarbon gases, and (2) they are substances that can be used in products that are sold on the open market in the US. Their physical and chemical characteristics require that they stay within rigorously contained systems within the manufacturing facility. Unlike Refinery Gases, Petroleum Hydrocarbon Gases do not contain inorganic compounds (*e.g.* hydrogen sulfide, ammonia, carbon monoxide) other than asphyxiant gases; the low molecular weight hydrocarbon molecules are primarily responsible for the hazard associated with the Petroleum Hydrocarbon Gases.

While there are 99 petroleum hydrocarbon gas substances in the Category, few reach the consumer. Some can be shipped to other manufacturing locations for further processing or for use as fuel.

Petroleum Hydrocarbon Gases Category Rationale

All Hydrocarbon Gases Category members contain primarily hydrocarbons (i.e., alkanes and alkenes). When inorganic components are present they consist of asphyxiant gases such as hydrogen.. Unlike other petroleum product categories (*e.g.* gasoline, diesel fuel, lubricating oils, etc.), the constituents of hydrocarbon gases can be evaluated for hazard individually, and the results of the constituent evaluation can then be used to predict the screening level hazards of the Category members. The constituents used to evaluate the hazards of Hydrocarbon Gases Category members are:

- Hydrocarbon Gases
  - Benzene
  - 1,3-Butadiene
  - C1 – C4 Hydrocarbons
  - C5 – C6 Hydrocarbons
- Asphyxiant Gases
  - Carbon dioxide
  - Hydrogen gas
  - Nitrogen gas

Physical-Chemical Properties and Environmental Fate

Petroleum hydrocarbon gases are mixtures of primarily hydrocarbons (i.e., alkanes and alkenes) and occasional inorganic gases (e.g., hydrogen, nitrogen, and carbon dioxide). The individual hydrocarbons in these gases typically have carbon numbers that range from C1 to C6, although the C1 to C4 consituents predominate, and the overall range of physical-chemical properties can be broad, as reflective of the molecular weights of these constituents. In general, most streams are composed of predominantly C1-C4 hydrocarbons, and these have extremely low melting and boiling points. They also have high vapor pressures and low octanol/water partition

coefficients. The aqueous solubility of these components varies, but the solubility of the majority of the hydrocarbons falls within a range of 22 mg/L to several hundred parts per million.

The environmental fate characteristics of petroleum hydrocarbon gases are governed by these physical-chemical attributes. All components of these gases will partition to the air where interaction with hydroxyl radicals is an important fate process. Hydrocarbons having molecular weights represented in these streams are inherently biodegradable, but their tendency to partition to the atmosphere would prevent their biotic degradation in water and soils. However, if higher molecular weight fractions of these streams enter the aquatic or terrestrial environment, biodegradation may be an important fate mechanism.

The inorganic gases are chemically stable and may be lost to the atmosphere or simply become involved in the environmental recycling of their atoms. Some show substantial water solubility, but their volatility eventually causes these gases to enter the atmosphere.

Environmental Effects

Acute LC/EC50 values for the hydrocarbon components of these gas streams ranged roughly from 1 to 100 mg/L. Although the LC/EC50 data for the individual gases illustrate the potential toxicity to aquatic organisms, aqueous concentrations from releases of these gases would likely not persist in the aquatic environment for a sufficient duration to elicit toxicity. Based on a simple conceptual exposure model analysis, emissions of petroleum hydrocarbon gases to the atmosphere would not likely result in acutely toxic concentrations in adjacent water bodies because such emissions will tend to remain in the atmosphere.

Human Health Effects

The screening level mammalian health hazards associated with Petroleum Hydrocarbon Gases have been characterized by the constituents (as listed above) of each petroleum hydrocarbon gas. Petroleum hydrocarbon gas constituent hazard data were used to characterize SIDS endpoints for each of the 99 Petroleum Hydrocarbon Gases in the category. To accomplish this, the endpoint value (acute LC_{50}, reproductive toxicity NOAEL/LOAEL, etc.) for a specific gas constituent has been adjusted for dilution of each constituent in the respective petroleum hydrocarbon gas. This adjustment for the dilution of each component in a petroleum hydrocarbon gas represents the calculated concentration of the petroleum hydrocarbon gas required to reach the toxicity value (LC_{50}, NOAEL, etc.) corresponding to the pure substance. For example, if the reproductive toxicity LOAEL for neat (100%) benzene is 300 ppm, the LOAEL for a petroleum hydrocarbon gas containing only 2% (wt./v) benzene would be fifty times more than 100% benzene, or 15,000 ppm; *i.e.* at a petroleum hydrocarbon gas concentration of 15,000 ppm, the benzene concentration would be 300 ppm, equal to its reproductive toxicity LOAEL value. In many cases, there is more than one potentially toxic constituent in a petroleum hydrocarbon gas. In those cases, the constitutent that is most toxic for a particular endpoint in an individual petroleum hydrocarbon stream is used to characterize the endpoint hazard for that stream. A more detailed explanation with examples of these calculations, along with the calculations for each of the 99 petroleum hydrocarbon gases used to determine which constituent to use to characterize mammalian SIDS endpoint-specific hazard for each gas is presented in the body of the document.

The hazard potential for each mammalian endpoint for each of the 99 petroleum hydrocarbon gases is dependent upon each petroleum hydrocarbon gas constituent endpoint toxicity values (LC50, LOAEL, etc.) and the relative concentration of the constituent present in that gas. It should also be noted that for an individual petroleum hydrocarbon gas, the constituent characterizing toxicity may be different for different mammalian endpoints, again, being dependent upon the concentration of the different constituents in each, distinct petroleum hydrocarbon gas.

1. DESCRIPTION OF PETROLEUM HYDROCARBON GASES CATEGORY

Background
The original Petroleum Gases Category of 161 substances has been split into two separate categories; (1) the Petroleum Hydrocarbon Gases Category, and (2) the Refinery Gases Category. This Category Analysis Document provides the HPV hazard characterization for the Petroleum Hydrocarbon Gases Category. This division of petroleum gases into two categories is more consistent with petroleum gas categories developed by CONCAWE (Conservation of Clean Air, Water in Europe; the European petroleum industry technical organization) and used in European Union legislation.

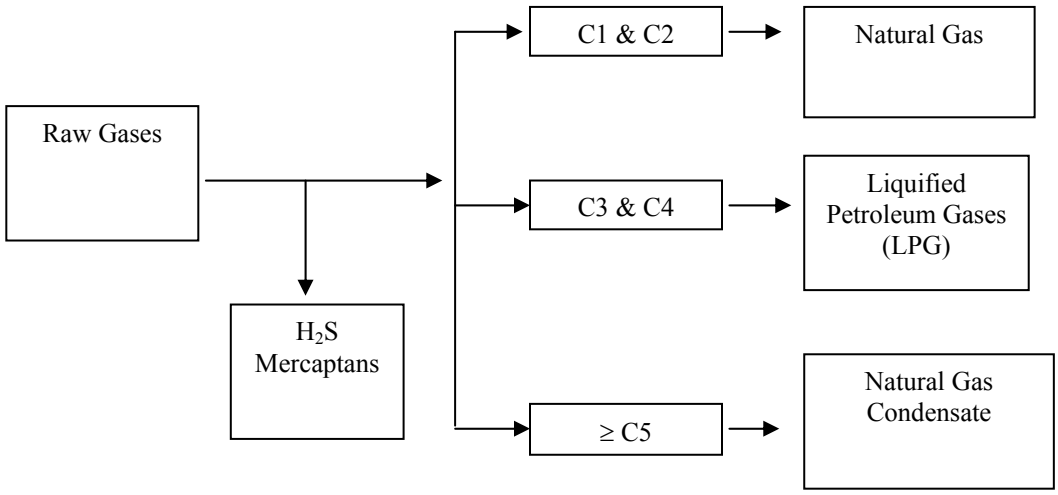
General Description of the Petroleum Hydrocarbon Gases Category
The Petroleum Hydrocarbon Gases Category contains 106 chemical substances. Of these 106 substances, 99 are petroleum hydrocarbon gases and 7 are individual supplemental chemicals:

- Ninety-two substances are petroleum petroleum hydrocarbon gases listed on the 1990 HPV substances list;
- Seven substances are petroleum hydrocarbon gases not listed on the 1990 HPV list; and
- Seven substances are included in the category as supplemental chemicals (four hydrocarbon and three asphyxiant gases)

The supplemental chemicals are included in this category to characterize the SIDS[1] endpoints for the petroleum hydrocarbon gases (as described below). These are included as single chemicals because they either exist in petroleum hydrocarbon gases at more than trace levels or are known to cause adverse effects in mammalian or aquatic organisms. A list of all category members by CASRN and their respective TSCA definition is provided in Appendix 1.

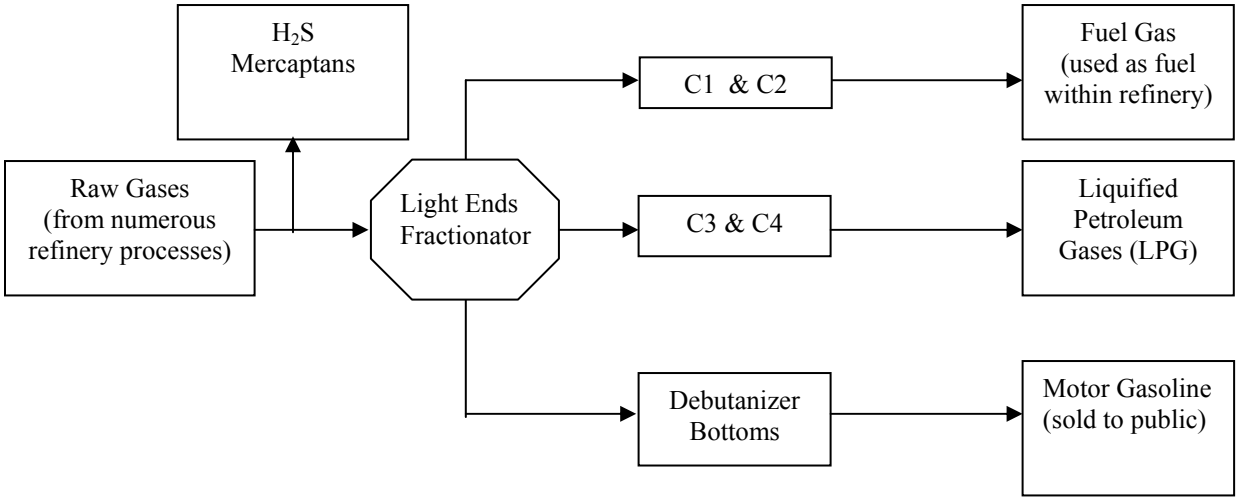
The 99 Petroleum Hydrocarbon Gas substances in this test plan are primarily produced in petroleum refineries as the light end fractions of numerous distillation and cracking processes, or in gas plants that separate natural gas and natural gas liquids. These gases exist as substances in closed systems in the refinery, with many of the gases being sold as finished products. All petroleum hydrocarbon gases in this category are comprised of predominantly one to four carbon atom hydrocarbons, and may contain asphyxiant gas components such as hydrogen, nitrogen, or carbon dioxide. Several petroleum hydrocarbon gases also contain benzene and/or butadiene. As with most of the substances handled within the petroleum industry, these gaseous substances are commonly referred to as "refinery streams." Simplified diagrams of how these substances are processed in Gas Plants and Refineries are given below:

Gas Plants



[1] SIDS = Screening Information Data Set

Refineries



A few of the gas streams contain only one component such as propane or butane, but most contain varying proportions of several components. Natural gas (methane) and liqified petroleum gas (LPG; predominantly propanes and butanes) are the two products from the Petroleum Gases category that are most commonly marketed to the general public. In addition to their use as fuels, some of the simple alkanes are used as propellants in spray cans. Most of these substances are identified on the Toxic Substances Control Act (TSCA) Chemical Inventory as Class II substances, "Chemical Substances of Unknown or Variable Composition, Complex Reaction Products and Biological Materials."

The defining characteristics of Petroleum Hydrocarbon Gases are that they (1) exist in a gaseous state at room temperature, (2) contain predominantly hydrocarbon compounds with 1 – 4 carbons, which are the dominant hazard in the substance, and (3) that after additional fractionation, are sold on the open market in the US as fungible products. Their physical and chemical characteristics require that they be maintained within rigorously contained systems. The potential for human and environmental exposures is associated with use of consumer products (*e.g.* commercial propane for gas barbeque grilling; natural gas for home heating and cooking), as well as accidental releases and/or spills. If accidental releases occur, *e.g.* from containment system ruptures or malfunctions, there could be releases of petroleum hydrocarbon gases. Aside from the potential for asphyxiaton at high concentrations, other dangerous conditions associated with catastrophic releases include the physical hazards of explosion and fire. Chronic occupational exposure to petroleum hydrocarbon gases at hazardous levels is unlikely to occur since preventing release of hydrocarbon and toxic gas is an integral component of refinery facility risk management programs (see Section 8. Human Exposure Summary, for more details).

The ecotoxicological hazards of petroleum hydrocarbon gases were assessed on the basis of the streams' principal components. Acute toxicity data for the three aquatic organism groups (i.e., fish, invertebrates, and algae) were reviewed for those principal components and an assessment was made based on their relative hazards. The results provided an indication as to which components would be important for hazard characterization for the individual streams. In this way, a simple assessment could be made regarding relative hazards of the streams.

The carbon number range of the Petroleum Hydrocarbon Gases hydrocarbons is predominantly C1 – C4. Many Petroleum Hydrocarbon Gases do contain C5 and C6 hydrocarbons. With the exception of the streams containing one essentially pure constituent (*e.g.* pentane, 2-butene, 2-methyl butane), these C4+ constituents are typically found at lower concentrations (wt.%) in gases than the C1 – C4 constituents. There are also a few category members that may contain C7 and even C8 hydrocarbons, although such streams would necessarily be at elevated temperature and/or pressure to maintain the C7 and C8 constituents in the gaseous state. Since hydrocarbon compounds containing C5, C6, C7, and C8 are found predominantly in petroleum naphthas, the hazards of these hydrocarbons have been characterized in the Gasoline Blending Streams Category. To account for any possible toxicity associated with the higher carbon number hydrocarbons, two categories of petroleum hydrocarbon gas constituents are being used for the hydrocarbon components of the petroleum hydrocarbon gases, C1 – C4 and C5 – C6; the

infrequently found C7 and C8 hydrcarbons are considered to be part of the C5-C6 fraction for hazard characterization of the individual hydrocarbon gas streams. Table 1 presents both the hydrocarbon classes and inorganic components found in the Petroleum Hydrocarbon Gases.

Table 1. Petroleum Hydrocarbon Gas Components

Category	Petroleum hydrocarbon gases	
Component Class	Hydrocarbons	Inorganics
Component CAS Number.	Alkanes (*e.g.* propane 74-98-6)	Hydrogen 1333-74-0
	Olefins (*e.g.* ethylene 74-85-1)	Nitrogen 7727-37-9
	Alkadienes (*e.g.* 1,3-butadiene 106-99-0)	Carbon dioxide 124-38-9
	Alkynes (*e.g.* ethyne 74-86-2)	
	Aromatics (*e.g.* benzene 71-43-2)	

The constituents of petroleum gases cover a range of toxicity. Accordingly, human health hazards would be overestimated if the overall hazards of the stream are assumed to be equal to those of the most hazardous of the individual constituents. Therefore, to more accurately characterize the human health hazards associated with these petroleum hydrocarbon gas streams, it is necessary to correct toxicity values (e.g. LC_{50}, repeated-dose LOAEL, etc.) associated with the gas constituents (C1 – C4 HCs, 1,3-butadiene, etc.) to the concentrations at which they are found in the various substances in order to reflect the dilution of that component in each specific petroleum hydrocarbon gas.

It should be noted that several of the components of petroleum hydrocarbon gases have extensive epidemiological and toxicological data available. It is beyond the scope of this document, and the HPV program, to thoroughly characterize the hazards associated with these compounds; that has been done elsewhere by the USEPA, NAS, ATSDR, IARC, ACGIH and other sources. The hazard information provided in this document will be limited to the HPV-required SIDS endpoints, as these are the endpoints that will be used to provide the screening level hazard data requested by USEPA for these High Production Volume petroleum hydrocarbon gases.

2. PETROLEUM HYDROCARBON GASES CATEGORY RATIONALE

All Hydrocarbon Gases Category members contain primarily hydrocarbons (i.e., alkanes and alkenes) and occasionally asphyxiant gases like hydrogen. The inorganic components of the hydrocarbon gases are less toxic than the C1 – C4 and C5 – C6 hydrocarbon components to both mammalian and aquatic organisms. Unlike other petroleum product categories (*e.g.* gasoline, diesel fuel, lubricating oils, etc.), the inorganic and hydrocarbon constituents of hydrocarbon gases can be evaluated for hazard individually to then predict the screening level

hazard of the Category members. The constituents identified to evaluate Hydrocarbon Gases Category member hazards are:

- Hydrocarbon Gases
    - C1 – C4 Hydrocarbons
    - C5 – C6 Hydrocarbons
    - Benzene
    - 1,3-Butadiene
- Asphyxiant Gases
    - Carbon dioxide
    - Hydrogen gas
    - Nitrogen gas

Two category members (CASRN 68476-85-7 and 68514-31-8) may contain a minimal amount (0.1% – 1.0%) of mercaptans[2]. Since this is only 2% (2 of 99 petroleum hydrocarbon gas category members) of the petroleum hydrocarbon gases, and the mercaptans make up a small fraction of the two substances in which they are found, they will not be treated as a separate constituent for hazard characterization in this category.

Grouping the hydrocarbon gases into a single category is reasonable from an ecotoxicological perspective. The majority of the components in hydrocarbon gases exist in the gaseous state at typical ambient temperatures. Hence, exposure scenarios would be similar among the different category members. Based on their physical-chemical characteristics, exposure of hydrocarbon gases to aquatic organisms would require transport from the atmosphere to the water compartment. While the aquatic toxicity of these hydrocarbons range from 1 to 100 mg/L, the Level 1 fugacity modeling of individual constituents (see Section 5.3.1) demonstrates that atmospheric releases would not result in levels of the gases in the aqueous compartment at levels sufficient to adversely affect aquatic biota. Aquatic SIDS hazard data are presented for the neat substance for selected hydrocarbon gas constituents. To assess and evaluate the potential hazards and risks to aquatic organisms of a catastrophic release of hydrocarbon gases, a conceptual exposure model was used that included inter-media transport of hydrocarbon gas constituents between the atmospheric and aquatic compartments. The constituents identified as most important for characterizing aquatic hazard were included in the conceptual exposure model.

The mammalian health hazards associated with Petroleum Hydrocarbon Gases were characterized by the constituents listed above. The SIDS endpoint toxicity values are provided in Section 7, Human Health Effects. These data were used to characterize SIDS endpoints for each of the 99 hydrocarbon gases in the category. To accomplish this, the endpoint values (acute LC_{50}, reproductive toxicity NOAEL/LOAEL, etc.) for a specific constituent have been adjusted to account for concentration of the consituent, using its minimum and maximum levels in each hydrocarbon gas. This adjustment for the dilution of each component in a petroleum hydrocarbon gas represents the calculated concentration of the petroleum hydrocarbon gas required to reach the toxicity value (LC_{50}, NOAEL, etc.) corresponding to the constituent in its pure state. For example, if the reproductive toxicity LOAEL for neat (100%) benzene is 300 ppm, the LOAEL for a petroleum hydrocarbon gas containing only 2% (wt./v) benzene would be fifty times more than 100% benzene, or 15,000 ppm; *i.e.* at a petroleum hydrocarbon gas concentration of 15,000 ppm, the benzene concentration would be 300 ppm, equal to its reproductive toxicity LOAEL value. The most toxic constituent for the particular endpoint is used to characterize the hazard for each petroleum hydrocarbon gas stream. A more detailed explanation with examples of these calculations, along with the calculations for each of the 99 petroleum hydrocarbon gases used to determine the endpoint specific hazard values

[2] Note on thiol compounds: Many petroleum hydrocarbon gases are odorless, so for safety reasons, thiol compounds (*e.g.* ethanethiol) may be added (post manufacture) to some petroleum hydrocarbon gases as odorants. These thiol compounds have very low odor thresholds (as low as 1 ppb). These odorants provide a sensory cue for potentially hazardous exposure from accidental leaks. If interested in the SIDS-level hazards associated with thiols and mercaptans, please see the Refinery Gases Category Analysis Document (API, 2009a) or the Mercaptans/Thiols Council's HPV submission (MTC, 2001) and the associated robust study summaries previously submitted to the USEPA.

for each gas is presented in Section 7.6 and Appendix 5, which is appended as a separate Excel™ spreadsheet file ("*Appen 5 dilution calcs HC gases – hlth endpts.xls"*)to this category analysis document.

3. PETROLEUM HYDROCARBON GASES CATEGORY MEMBER SELECTION CRITERIA

Appendix 1 provides a complete listing of substances included in the Petroleum Hydrocarbon Gases category.

The primary criteria for placing a gas into this category was the absence of significant concentrations of inorganic compounds other than asphyxiant gases, in the petroleum hydrocarbon stream, as had been done previously by CONCAWE in their "Petroleum Gases" Category. The 161 petroleum gases in the original Petroleum Gases Category were compared to the CONCAWE *"Petroleum Gases Group"* and overlapping CASRNs were put into the API Petroleum Hydrocarbon Gases Category. The remaining, non-overlapping CASRNs were reviewed and expert judgment was used to select the remaining category member candidate list. Table 2 provides examples of petroleum hydrocarbon gas TSCA definitions and typical compositional ranges for constituents. A complete list of the constituents associated with each category member can be found in Appendix 2.

Table 2. Examples of Category Member TSCA Definitions and Typical Constituent Composition

CAS Number	Petroleum Petroleum Hydrocarbon Gas Name	TSCA Definition	Petroleum Hydrocarbon Gas Constituent Composition[1]
8006-14-2	Natural gas	Raw natural gas, as found in nature, or a gaseous combination of hydrocarbons having carbon numbers predominantly in the range of C1 through C4 separated from raw natural gas by the removal of natural gas condensate, natural gas liquid, and natural gas condensate/natural gas.	C1-C4 = 89.5 to 94.1%; Hydrogen = 5 to 10%; Nitrogen = 0.1 to 0.5%
68131-75-9	Gases (petroleum), C3-4	A complex combination of hydrocarbons produced by distillation of products from the cracking of crude oil. It consists of hydrocarbons having carbon numbers in the range of C3 through C4, predominantly of propane and propylene, and boiling in the range of approximately -51°C to -1°C (-60°F to 30°F).	C1-C4 = 100%; 1,3-Butadiene = 0 to 0.1%
68307-98-2	Tail gas (petroleum), catalytic cracked distillate and catalytic cracked naphtha fractionation absorber	The complex combination of hydrocarbons from the distillation of the products from catalytic cracked distillates and catalytic cracked naphtha. It consists predominantly of hydrocarbons having carbon numbers in the range of C1 through C4.	C1-C4 = 96.5 to 100%; C5-C5 = 0 to 1%; Hydrogen = 0 to 2%; Carbon dioxide = 0 to 0.5%; Butadiene = 0.1 to 2%

[1] Analytical data from multiple CASRN samples obtained from multiple refineries. See Appendix 2 for a description of sample collection and analysis.

It should be noted that Section 8(b) of the Toxic Substances Control Act required identification and registration with the Environmental Protection Agency of each "chemical substance" being manufactured, processed, imported or distributed in commerce. Products from the refining of crude oil and raw natural gas feed are rarely, if ever, sold by TSCA Inventory identifiers. The refining and sale of petroleum products pre-dates

development of CAS and TSCA nomenclature. The fungible products that leave a refinery are sold based on the product meeting certain performance, physical, or chemical specifications which make them fit for purpose (i.e, HD-5 propane, "on-road" diesel fuel, illumination grade kerosene, and USP white mineral oil).

The TSCA substance definitions were not intended to list all constituents that would be important for hazard characterization. As can be seen in Table 2, the descriptions accompanying the CASRN of each petroleum gas are written in broad, general terms. The descriptions may contain concentration ranges, however, most CASRN descriptions provide qualitative rather quantitative analytical information. Since CASRN descriptions for petroleum streams, including the petroleum hydrocarbon gases, were intentionally written to be qualitative in nature, they may or may not specifically list all of the consituents that could be present in a specific gas stream. The approximate composition (*i.e.* inorganic and hydrocarbon components) for each of the 99 petroleum hydrocarbon gases in TSCA CASRN order can be found in Appendix 2.

4. PHYSICAL-CHEMICAL PROPERTIES

Members of the Hydrocarbon Gases Category are mixtures of primarily low molecular weight alkanes and alkenes with occasional inorganic gases, hydrogen, nitrogen, and carbon dioxide. If present, these inorganic gases constitute a relatively small fraction of the total content of these streams. In contrast, they are much more prevalent in the Refinery Gases Category, and their physical-chemical properties are addressed in that document (API, 2009a). The physical-chemical properties are provided here because they may be present in these gas mixtures.

Physical-chemical properties are reported here for various isomeric hydrocarbon structures of the different types found in category members of the Hydrocarbon Gases. While the proportions of the hydrocarbons in these streams are highly variable, the predominant hydrocarbon chain lengths range from C1 to C6. The chain length groups are divided into C1 to C4 hydrocarbons and C5 to C6 hydrocarbons. The latter group overlaps with gasoline naphthas and are the predominant hydrocarbon chain lengths in those petroleum streams. Physical-chemical properties of the gasoline naphthas are thoroughly described in detail in the Gasoline Blending Streams Category Analysis Document (API, 2008a). Additionally, butadiene and benzene are two hydrocarbon compounds that have particular human health hazards and may be present as part of the hydrocarbon gas streams. Therefore, the physical-chemical properties of benzene and butadiene are also listed in the subsequent sections.

4.1 Physical-Chemical Endpoints

The physical-chemical endpoints in the HPV chemicals program include the following:

- Melting Point
- Boiling Point
- Vapor Pressure
- Octanol/Water Partition Coefficient
- Water Solubility

When measured values were not available from the literature, values were estimated using structure activity relationships employed by EPI-Suite™ (US EPA, 2000a).

4.1.1 Melting Point

Melting point values for the C1 to C4 hydrocarbons and inorganic constituents are given below.

Constituents:	Melting Point, °C	Reference
C1-C4 Hydrocarbons		
Methane	-182	Lide (1990-1991)

Ethane	-183.3	Lide (1990-1991)
Ethylene	-169	Lide (1990-1991)
Propane	-189.7	Lide (1990-1991)
Propylene	-185	O'Neil (2001)
n-butane	-138.4	Lide (1990-1991)
Isobutane	-159.4	Lide (1990-1991)
1,3-butadiene	-109	Budavari (1996)
Isobutylene	-140.4	Lide (1998-1999)
Inorganic Gases		
Hydrogen	-259	Budavari (1996)
Nitrogen	-210	Budavari (1996)
Carbon dioxide	-56.5	Lide and Milne (1994)

Other hydrocarbons:
C5 and C6 hydrocarbons of various classes (alkanes, alkenes, naphthenes, aromatics) and isomeric structures have melting points that range from -169°C (isopentene) to 6.5°C (cyclohexane) (Lide, 1998-1999; Budavari, 1996). The melting point of benzene is 5.5°C (Budavari, 1996).

4.1.2 Boiling Point

Boiling point values for the C1 – C4 hydrocarbons and inorganic constituents are given below.

Constituents :	Boiling Point °C	Reference
C1-C4 Hydrocarbons		
Methane	-164	Lide (1990-1991)
Ethane	-88.6	Lide (1990-1991)
Ethylene	-102.4	Lide (1990-1991)
Propane	-42.1	Lide (1990-1991)
Propylene	-48	O'Neil (2001)
n-butane	-0.5	Lide (1990-1991)
Isobutane	-11.7	Lide (1990-1991)
1,3-butadiene	-4.5	Budavari (1996)
Isobutylene	-6.9	Lide (1998-1999)
Inorganic Gases		
Hydrogen	-252.8	Budavari (1996)
Nitrogen	-196	Budavari (1996)
Carbon dioxide	-78.5	Lide and Milne (1994)

Other hydrocarbons:
C5 and C6 hydrocarbons of various classes (alkanes, alkenes, naphthenes, aromatics) and isomeric structures have boiling points that range from 20°C (isopentene) to 81°C (cyclohexane) (Lide, 1998-1999; Budavari, 1996). The boiling point of benzene is 80.1°C (Budavari, 1996).

4.1.3 Vapor Pressure

Estimated or measured vapor pressures for the C1 – C4 hydrocarbons and inorganic constituents in hydrocarbon gases are given below.

Constituents:	Vapor Pressure hPa @ 25°C	Reference
C1-C4 Hydrocarbons		

Methane	621,282	Daubert and Danner (1989)
Ethane	41,942	Daubert and Danner (1989)
Ethylene	69,461	Daubert and Danner (1989)
Propane	9,533	Daubert and Danner (1989)
Propylene	11,586	Daubert and Danner (1989)
n-butane	2,426	Riddick et al. (1985)
Isobutane	3,481	Riddick et al. (1985)
1,3-butadiene	2,813	Daubert and Danner (1989)
Isobutylene	3,077	Yaws (1994)
Inorganic Gases		
Hydrogen	1,653,198	Ohe (1976)
Nitrogen	1,013[1]	Weast (1984)
Carbon dioxide	64,395	Dauber and Danner (1989)

[1] Value reported for a temperature of -196°C

Other hydrocarbons:
C5 and C6 hydrocarbons of various classes (alkanes, alkenes, naphthenes, aromatics) and isomeric structures have vapor pressures that range from 126 hPa (benzene) to 1204 hPa (isopentene) (Daubert and Danner, 1989; Yaws, 1994). The vapor pressure of benzene is 126 hPa (Daubert and Danner, 1989).

4.1.4 Octanol:Water Partition Coefficient (Log Kow)

Estimated or measured log Kow values for the C1 – C4 hydrocarbons and inorganic constituents in hydrocarbon gases are given below.

Constituents:	Log Kow	Reference
C1-C4 Hydrocarbons		
Methane	1.09	Hansch, et al. (1995)
Ethane	1.81	Hansch, et al. (1995)
Ethylene	1.13	Hansch, et al. (1995)
Propane	2.36	Hansch, et al. (1995)
Propylene	1.77	Hansch, et al. (1995)
n-butane	2.89	SRI International (2000)
Isobutane	2.76	Hansch, et al. (1995)
1,3-butadiene	1.99	Hansch, et al. (1995)
Isobutylene	2.34	Hansch, et al. (1995)
Inorganic Gases		
Hydrogen	N/A	
Nitrogen	0.67	Hansch et al. (1995)
Carbon dioxide	0.83	US EPA (2000a)

Other hydrocarbons:
C5 and C6 hydrocarbons of various classes (alkanes, alkenes, naphthenes) and isomeric structures have partition coefficients (Log Kow) that range from 2.13 (benzene) to 3.9 (hexane) (Hansch et al., 1995).

4.1.5 Water Solubility

Estimated or measured water solubility values for the organic and inorganic constituents in petroleum hydrocarbon gases are given below.

Constituents:	Water Solubility mg/L @25°C	Reference
C1-C4 Hydrocarbons		
Methane	22	Yalkowsky and Yan (2003)
Ethane	60.2	McAuliffe (1966)
Ethylene	131	McAuliffe (1966)
Propane	62.4	Yalkowsky and Yan (2003)
Propylene	200	McAuliffe (1966)
n-butane	61.2	McAuliffe (1966)
Isobutane	48.9	McAuliffe (1966)
1,3-butadiene	735[1]	McAuliffe (1966)
Isobutylene	263	Yalkowsky and Dannenfelser (1992)
[1] Value reported for a temperature of 20°C		
Inorganic Gases		
Hydrogen	1.62	Venable and Fuwa (1922)
Nitrogen	18,100	US EPA (2000a)
Carbon dioxide	1,480	US EPA (2000a)

Other hydrocarbons:
C5 and C6 hydrocarbons of various classes (alkanes, alkenes, naphthenes) and isomeric structures have water solubility values that range from 9.5 mg/L (hexane) to 1790 mg/L (benzene) (McAullife, 1966; May et al., 1983).

4.2 Assessment Summary for Physical-Chemical Endpoints

The different hydrocarbon constituents making up the category members of hydrocarbon gases present a wide range of physical-chemical characteristics, and no unique set of physical-chemical endpoints would represent the entire category. However, the majority of these streams contain hydrocarbons of C1 to C4 chain lengths and for these category members the low boiling points of the constituent hydrocarbons reflect their typical gaseous state. Other category members having higher proportions of C5 to C6 hydrocarbons would be expected to behave according to the physical-chemical attributes of these higher chain length compounds.

5. ENVIRONMENTAL FATE

As noted in previous sections, members of the Petroleum Hydrocarbon Gases Category contain primarily hydrocarbon compounds having one to six carbon atoms and hydrogen, nitrogen, and carbon dioxide gases in minor amounts. Proportions of these constituents in the hydrocarbon gas streams vary and may make up significant or minor portions of these streams.

When a substance such as one of the Hydrocarbon Gases streams is released into the environment, the individual constituents separate and partition to the different environmental compartments in accordance with their own physical-chemical properties. The ultimate fates of the individual components in Hydrocarbon Gases are influenced by both abiotic and biotic processes, and the relative importance of these processes will depend upon the environmental compartment to which the individual components partition.

The individual streams within the Hydrocarbon Gases Category are not uniquely different among themselves. The key difference is the proportions of common hydrocarbons that they contain. By understanding the environmental fate characteristics of its individual components, an overall assessment of an entire stream is possible. Therefore,

the environmental fate attributes of the key individual constituents in Hydrocarbon Gases are described in the following sections.

5.1 Environmental Fate Endpoints

The US EPA has selected the following environmental fate endpoints by which these substances may be characterized.

- Photodegradation,
- Stability in water (hydrolysis),
- Environmental distribution (fugacity), and
- Biodegradation.

In determining these fate characteristics for constituents in Hydrocarbon Gases, the USEPA's collection of physical-chemical and environmental fate models in EPI Suite™ (US EPA, 2000a) were used to estimate the properties of photodegradation, stability in water, and environmental distribution. Measured data, when available, were included in the assessment. Biodegradation was examined for these substances in light of their physical-chemical properties and their capacities to undergo microbial oxidation/reduction reactions.

5.1.1 Photodegradation

5.1.1.1 Direct Photodegradation

A prerequisite for direct photodegradation is the ability of one or more bonds within a chemical to absorb ultraviolet (UV)/visible light in the 290 nm to 750 nm wavelength range. Light wavelengths longer than 750 nm do not contain sufficient energy to break chemical bonds, while wavelengths below 290 nm are shielded from the earth by the stratospheric ozone layer (Harris, 1982a).

Direct photodegradation of hydrocarbons is not expected to be an important fate process for these constituents. Saturated hydrocarbons (paraffins and naphthenes), olefins with one double bond, and single ring aromatics do not absorb appreciable light energy above 290 nm. Therefore direct photodegradation would not be expected to occur for these compounds.

For the inorganic gases, their capacities to undergo direct photodegradation was assessed and described as follows.

Hydrogen. Hydrogen gas (H_2) has such low density that it easily escapes from the earth's gravitational pull. Therefore it is only a minor constituent of the atmosphere (Boikess and Edelson, 1978). The H─H bond has a large bond energy so dissociation only occurs at extreme temperatures (e.g., >2000°K). This property makes hydrogen gas un-reactive in the troposphere.

Nitrogen. Nitrogen gas (N_2) in the atmosphere is relatively non-reactive due to its strong bond. Therefore, direct photodegradation is not likely to occur. The atmosphere serves as a reservoir from which nitrogen is constantly removed by the action of electrical discharge and nitrogen-fixing bacteria and algae. Atmospheric inputs of nitrogen gas come from reduction of nitrates and nitrites, and the anaerobic decomposition of organic matter (Sawyer and McCarty, 1978).

Carbon Dioxide. Carbon dioxide is a stable compound (Boikess and Edelson, 1978). It is a relatively minor constituent in the atmosphere. It shows no spectral absorbance in the 290 – 750 nm range, thus direct photodegradation is not likely to occur.

5.1.1.2 Indirect Photodegradation

Constituents of Hydrocarbon Gases that volatilize to air may undergo a gas-phase oxidation reaction with photochemically produced hydroxyl radicals (OH^-). Atmospheric oxidation as a result of hydroxyl radical attack is not direct photochemical degradation, but indirect degradation (Schwarzenbach et al, 2003). The atmospheric oxidation potential (AOP) of the major constituents in Hydrocarbon Gases was estimated using AopWin (atmospheric oxidation program for Microsoft Windows), a subroutine in the EPI Suite™ (USEPA, 2000a) models and used by the US EPA OPPTS (Office of Pollution Prevention and Toxic Substances). This program calculates a reaction rate constant (cm^3/molec-sec) and a chemical half-life (hour or days) of a compound based upon average atmospheric concentrations of hydroxyl radicals (1.5×10^6 OH^-/cm^3) and a 12-h day at 25°C.

Indirect photodegradation of the hydrocarbon components in Hydrocarbon Gases can be an important fate process for these constituents. In general, half lives decrease with increasing carbon chain length. For the C1-C4 constituent gases, degradation half-lives for the reaction with hydroxyl radicals in the troposphere were calculated according to Atkinson (1990) and reported in the robust summaries. Half-lives determined in this manner ranged from 3.2 days (n-butane) to 960 days (methane). The C5-C6 hydrocarbon constituents ranged from 0.2 days (isopentene) to 5.5 days (benzene).

For the inorganic gases, an overview of their potential to react with hydroxyl radicals was taken from general references.

Hydrogen. As noted for direct photodegradation potential, hydrogen gas (H_2) has such low density that it easily escapes from the earth's gravitational pull and is only a minor constituent of the atmosphere (Boikess and Edelson, 1978). The H─H bond has a large bond energy so dissociation only occurs at extreme temperatures (e.g., >2000°K). This property makes hydrogen gas un-reactive in the troposphere.

Nitrogen. Nitrogen gas (N_2) in the atmosphere is relatively non-reactive due to its strong bond. Therefore, indirect photodegradation is not likely to occur. Atmospheric nitrogen is removed by nitrification processes (Sawyer and McCarty, 1978).

Carbon dioxide. As noted for direct photodegradation, carbon dioxide is chemically stable and is a relatively minor constituent in the atmosphere (Boikess and Edelson, 1978).

5.1.2 Stability in Water (Hydrolysis)

Compound types that are known to hydrolyze include alkylhalides, amides, carbamates, carboxylic acid esters and lactones, epoxides, phosphate esters, and sulfonic acid esters (Harris, 1982b). The hydrocarbon and inorganic constituents in the Hydrocarbon Gases category do not contain the functional groups or chemical linkages known to undergo hydrolysis reactions. Therefore hydrolysis will not play an important role in the environmental fate for the components in Hydrocarbon Gas streams.

5.1.3 Environmental Distribution (Fugacity)

Equilibrium models can provide information on where a chemical is likely to partition in the environment. These data are useful in identifying environmental compartments that could potentially receive a released chemical. A widely used fugacity model is the EQC (Equilibrium Criterion) model (Mackay et al., 1996, 1997). In its guidance document for HPV data development, the USEPA states that it accepts Level I fugacity data as an estimate of chemical distribution values. The EQC model is a Level I model that describes the equilibrium distribution of a fixed quantity of conserved (i.e., non-reacting) chemical at steady state within a closed environment with assumed volumes of air, water, soil and sediment. The model assumes the chemical becomes instantaneously distributed to an equilibrium condition using physical-chemical properties to quantify the chemical's behavior. The model does not include degrading reactions, advective processes or inter-media transport between compartments.

Results of Level I models are basic partitioning data that allow for comparisons between chemicals and indicate the compartment(s) to which a chemical is likely to partition in the environment. Hydrocarbon gases of the C1 to C4 and the C5 to C6 groups were assessed for their potential environmental distribution using the EQC model (Mackay et al., 1996, 1997). The inorganic gases (H_2, N_2, CO_2) typically have very low boiling points. These substances exist as gases at most ambient environmental temperatures.

Results show that the atmosphere is the environmental compartment to which these hydrocarbon constituents will partition. Results of the modeling are shown in Table 3.

Table 3. Results of EQC Level 1 Environmental Distribution Modeling of Important Components in Petroleum Hydrocarbon Gases

	Environmental Compartment, Percent Distribution					
Petroleum Hydrocarbon Gas Constituent	**Air**	**Water**	**Soil**	**Sediment**	**Suspended Particles**	**Biota**
C1 to C4	100%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
C5 to C6[1]	99.8 – 100%	<0.1%	<0.1 – 0.2	<0.1%	<0.1%	<0.1%

[1] The C5 to C6 hydrocarbons included representatives of n-, iso-, and cyclo- alkanes, alkenes, and aromatics.

5.1. Biodegradation

Some of the non-hydrocarbon constituents of the Petroleum Hydrocarbon Gases would not be expected to biologically degrade as these substances do not contain the chemical linkages necessary for microbial metabolism. For this reason, hydrogen, nitrogen, and carbon dioxide would not be susceptible to biodegradation. Furthermore, carbon dioxide is the final product in the biological mineralization of organic compounds.

Although volatilization largely determines environmental distribution of hydrocarbon gases, some constituents have sufficient aqueous solubility that they might be present in aqueous environments at sufficient levels and dor sufficient times to make them potentially availabe for microbial metabolism. Gaseous hydrocarbons are widespread in nature and their use as a carbon source for cell growth has been reported to be common among autotrophic organisms (Vestal, 1984). Some microbes have evolved that are capable of utilizing these substances as their sole energy source (Fuerst and Stephens, 1970; Stephens et al, 1971; O'Brien and Brown, 1967). Higher chain length hydrocarbons typical of naphtha streams (e.g., C5 and C6 hydrocarbons) have been shown to be inherently biodegradable in the environment (API, 2008a).

5.2 Assessment Summary for Environmental Fate

The members of the Petroleum Hydrocarbon Gases Category are made up of mostly hydrocarbon compounds, and their environmental fate characteristics are governed to a great extent by their physical-chemical attributes. Inorganic gases existing in minor quantities include hydrogen, nitrogen and carbon dioxide. All hydrocarbon components of hydrocarbon gases have been shown to partition to air, where interaction with hydroxyl radicals can be an important fate process. If released to the environment in a manner such that they become available to microbial populations, hydrocarbon constituents may be utilized and biodegraded. These hydrocarbon gases are not likely to persist in the environment.

6. ENVIRONMENTAL EFFECTS

6.1 Aquatic Toxicity

In context of the factors affecting potential exposure of aquatic organisms to Hydrocarbon Gases, acute toxicity from a catastrophic release is considered the primary concern. While chronic effects may be observed in laboratory tests where long-term exposures can be maintained, the low level exposures from fugitive environmental releases are not likely to impact aquatic systems. As described in previous sections, these substances exist in the gaseous phase at the refinery and are contained in closed systems. If released inadvertently, these substances would partition to the air and are not likely to enter aquatic environments.

N_2, H_2, and CO_2 are not known to be directly toxic to aquatic organisms. While direct release of these substances to water (e.g., bubbled through the water column) may result in oxygen displacement, potentially resulting in death due to asphyxiation, no information on their being directly toxic to aquatic life was found. Therefore they were not considered further in this evaluation, but may be considered as potential asphyxiants under specific aquatic release scenarios. However, other constituent hydrocarbons in hydrocarbon gases have well documented aquatic hazards and were considered potential toxic constituents in these streams. Available aquatic toxicity data for these substances were tabulated and presented below.

6.2 Aquatic Endpoints – Acute Toxicity

The HPV Chemical Test Program includes acute toxicity to a freshwater fish, an invertebrate (*Daphnia magna*), and an alga. The hazard evaluation included the evaluation of the principal hydrocarbon structures and isomers for the various predominant carbon chain lengths in these streams. Data cited in US EPA's ECOTOX database (U.S. EPA, 2007a) and the European Chemicals Bureau ESIS Database (ECB, http://ecb.jrc.ec.europa.eu/esis/) were reviewed. Ranges of toxicity endpoints (i.e., LC50, EC50 values) were noted for the various constituents in Hydrocarbon Gases. When empirical toxicity data was lacking, the ECOSAR model in EpiSuite™ (U.S. EPA, 2000a) was used to derive estimated LC/EC50 values.

The aquatic hazard data was assembled for the principal isomeric hydrocarbon structures and covered the specific compounds for which physical-chemical data were reported. The Hydrocarbon Gas constituents of interest show the following ranges of toxicity values for fish, invertebrates, and algae (Table 4). Endpoint values for the C1-C4 and the C5-C6 (excluding benzene) were estimated using ECOSAR with user-input values for measured water solubility and measured/estimated partition coefficient. Values for benzene were empirical data taken from the referenced citations.

Table 4. Acute Toxicity Data for Petroleum Hydrocarbon Gas Constituents to Aquatic Organisms

	Range of Toxicity Endpoint Values		
	Fish LC50, mg/L	**Invertebrate EC50, mg/L**	**Algae EC50, mg/L**
C1 – C4 hydrocarbons[1]	6.3 – 137	7.2 – 138	4.7 – 82
C5 – C6 hydrocarbons (naphthas)[1]	1.0 – 18	1.3 – 20	0.9 – 13
Benzene[2]	5.3 – 35.7	59.6 – 682	29

Note: Ecosar estimates of LC/EC50 values were made with user-input measured or estimated data for water solubility and partition coefficient. C1-C4 group hydrocarbons were methane, ethane, ethylene, propane, propylene, n-butane, isobutane, 1,3-butadiene, isobutylene. C5-C6 group hydrocarbons were pentane, isopentane, cyclopentane, isopentene, cyclopentene, hexane, isohexane,

cyclohexane.
Data Sources:
[1] US EPA (2000a)
[2] DeGraeve, et al. (1982); Brooke (1987); MacLean and Doe (1989); Eastmond et al. (1984); Galassi et al., (1988)

The data in Table 4 shows the longer-chained hydrocarbons to be somewhat more toxic to aquatic organisms than the shorter chained compounds. This relationship has been observed and reported elsewhere (Adema and van den Bos Bakker, 1986) and appears to hold true until the limits of solubility prevent toxic levels of hydrocarbons in the dissolved phase to be achieved. Water solubility is inversely proportional to the carbon number, and the point will eventually be reached at which no effects are seen at the highest concentrations that are possible to test. For the range of hydrocarbons that are found in the hydrocarbon gases streams, most of the toxicity values fall within the range of 1 to 100 part per million. Except for benzene, the data in Table 4 are estimated by structure activity relationships. However, as a practical point, the volatility of these gaseous materials makes it difficult to conduct aquatic toxicity tests using standard guideline techniques. Similarly, the volatility of these gases make it unlikely that environmental releases would persist in the aquatic environment at sufficient concentrations and for sufficient durations to cause adverse effects.

As a means to assess whether water concentrations of these substances could reach acutely toxic levels following an atmospheric release of petroleum hydrocarbon gases, a Level 3 fugacity model was run on individual components representing the predominant carbon number range for hydrocarbon gases. Input data included specific physical-chemical values for boiling point, melting point, vapor pressure, octanol-water partition coefficient, and water solubility for each substance. The model was run using an emission rate of 1000 kg/hr to the atmosphere for one hour. The concentration of each substance then was calculated assuming an aquatic compartment of 2×10^{11} m^3 (equivalent to 2×10^{14} L). While these substances typically do not constitute 100% of any petroleum hydrocarbon gas, the model cannot assess the properties of complex substances. Thus, the resulting calculations reflect the concentrations following release of these constituents in their pure state. Table 5 illustrates the results of the Level 3 model and the estimated water concentrations of the constituents.

Table 5. Results of Level 3 Fugacity modeling and Calculation of Water Concentrations

	Methane	Ethane	1-Propene	Butane	Isobutane	Pentane	Benzene
Water Solubility, mg/L	22	60	200	61	48.9	38	1,790
Henry's LC, atm-m^3/mole	6.6×10^{-1}	5.0×10^{-1}	2.0×10^{-1}	9.5×10^{-1}	1.19	1.3	5.6×10^{-3}
Mass amount in compartment, %							
air	56.8	55	10.7	47.9	44.3	42.1	37.6
water	42.6	44.3	87.6	50.1	54.2	54	48.1
soil	0.502	0.593	1.47	1.38	0.951	2.49	14.1
sediment	0.0871	0.13	0.249	0.531	0.586	1.33	0.219
Half Life in Compartment, hr							
air	37400	958	6.97	101	110	65.2	209
water	360	360	360	208	360	208	900
soil	720	720	720	416	720	416	1800
sediment	3240	3240	3240	1870	3240	1870	8100
Calculated concentration in water, mg/L							

	2.13×10^{-6}	2.22×10^{-6}	4.38×10^{-6}	2.51×10^{-6}	2.71×10^{-6}	2.70×10^{-6}	2.41×10^{-6}
Toxicity Conclusions:	no toxicity	no toxicity	no toxicity	no toxicity	no toxicity	no toxicity	no toxicity

From the data shown by the Level 3 fugacity model, a significant proportion of the petroleum gases may partition to water. Even so, the resulting aqueous concentrations of these gases would be expected to be extremely low and below levels predicted to be acutely toxic by ECOSAR. Therefore, no toxicity is predicted from atmospheric emissions of these hydrocarbon gases.

6.4 Assessment Summary for Environmental Effects

The hazard of hydrocarbon constituents in hydrocarbon gas streams to aquatic organisms was evaluated by estimating LC/EC50 values for fish, *Daphnia* sp., and algae. The endpoint values typically decreased with increasing number of carbon atoms and fell within the range of approximately 1 to 100 mg/L. Given the physical-chemical characteristics of the hydrocarbon gases and the confined production systems within refineries, potential exposures to aquatic organisms would be greatest from accidental catastrophic releases. The low environmental concentrations associated with fugitive emissions from refineries would not be expected to impact aquatic systems. Environmental concentrations from accidental or fugitive release associated with consumer use is also expected to be small. Based on a simple conceptual exposure model analysis, releases of hydrocarbon gases to the atmosphere would not likely result in acutely toxic concentrations in adjacent water bodies.

7. HUMAN HEALTH EFFECTS

For substances in the Petroleum Hydrocarbon Gases Category, human health hazard potential has been evaluated by characterizing petroleum hydrocarbon gas constituent's hazards, and then assessing the contribution to overall hazard of the substance by accounting for the constituent concentrations in the substance. As previously mentioned, it would overestimate the human health hazard of any petroleum hydrocarbon gas stream to assume that the toxicity of the stream is equal to that of any individual constituent. The Petroleum Hydrocarbon Gases may contain multiple components, which serve to dilute the concentration of any one constituent. Therefore to more accurately characterize the potential human health hazards associated with these gases, it is necessary to correct the pure (100%) constituent toxic potential, such as the C1 – C4 hydrocarbon fraction or 1,3-butadiene, to the concentrations of those constituents in each specific petroleum hydrocarbon gas. Since the streams are not 100% of any one constituent, calculations to account for this dilution effect were made for all constituents present in each petroleum hydrocarbon gas category member. The most toxic constituent for each human health endpoint was then selected to characterize the hazard for that stream for that endpoint. Please see Section 7.6 for more details on the hazard characterization method. Table 11 presents the calculated values for each human health endpoint for each of the 99 petroleum hydrocarbon gas category members. Calculations to determine the appropriate component to characterize the hazard for each mammalian endpoint in each petroleum hydrocarbon gas are presented in the Excel™ spreadsheet ("*Appen 5 dilution calcs HC gases – hlth endpts.xls*") submitted with this category analysis document.

The following sections summarize existing USEPA HPV SIDS endpoint key studies for benzene, 1,3-butadiene, C1 – C4 hydrocarbon fraction and C5 – C6 hydrocarbon light naphtha hydrocarbon fraction. The key studies selected are tabulated by endpoint in Appendix 3.

The key studies for the C1 – C4 hydrocarbon fraction were selected after review of toxicity data on individual C 1 – C4 hydrocarbons (***e.g.*** ethane, propane, acetylene, etc.). To enable an accurate review of the hazards associated with individual C1 – C4 gases, six new toxicity studies were conducted. OECD 422 Combined Repeated Dose Toxicity with the Reproduction/Developmental Toxicity Screening Tests were conducted on ethane, propane, butane and

isobutane (HLS 2008 a,b,c,d). An OECD 413 Subchronic Inhalation Toxicity: 90-day Study supplemented with an OECD 474 Mammalian Erythrocyte Micronucleus Test was conducted on liquefied petroleum gas (HLS 2008e). A developmental toxicity was also conducted on LPG: OECD 414 Prenatal Developmental Toxicity Study (HLS, 2009). After review of the new and existing data on the individual C1 – C4 HCs, the hydrocarbon with the lowest effect level was selected to represent the C1 – C4 HC fraction toxicity for each endpoint. The most toxic individual C1- C4 HC varied by endpoint. By selecting one hydrocarbon to represent the entire C1-C4 HC fraction, it is assumed that the toxicity of the entire C1- C4 fraction concentration in each HC-containing petroleum hydrocarbon gas is equivalent to that of the selected individual HC for a specific mammalian SIDS endpoint. This is an intentionally conservative approach. For example, the C1-C4 HC with the lowest effect level used to characterize repeated-dose toxicity is 2-butene; for predicting repeated-dose toxicity, a petroleum hydrocarbon gas containing 5 – 10% C1- C4 HCs is assumed to be equivalent to a gas containing 5 – 10% 2-butene, without other C1 – C4 HCs present. Please see Appendix 4 for a list of the C1 – C4 data evaluated for key study selection. As can be seen in the key study summaries below and tabulated in Appendix 4, none of the newly tested gases (ethane, propane, butane, isobutane, and LPG) were the most toxic C1 – C4 gases for repeated dose, *in vivo* genotoxicity (MN), or developmental toxicity. In contrast to all other C1 – C4 alkanes, alkenes, and LPG, reproductive toxicity was observed for isobutane in the newly conducted OECD 422 screening assay, and was thus selected to characterize the C1-C4 hydrocarbon fraction reproductive toxicity hazard,

The C5 – C6 light naphtha hydrocarbon fraction endpoint values were read across from SIDS endpoint values presented in detail in the Gasoline Blending Stream Category Analysis Document previously submitted to USEPA (API, 2008a). Whenever possible, naphtha light ends fraction testing conducted in compliance with the Clean Air Act 211(b) testing requirements were read across to the C5 – C6 hydrocarbons (US EPA, 1994a).

The human health SIDS endpoints are not provided for the three inorganic constituents that are simple asphyxiants (hydrogen, nitrogen and carbon dioxide),. If hydrogen, nitrogen, or carbon dioxide are present in a specific petroleum hydrocarbon gas, it was assumed that toxicity would only occur at or above asphyxiant levels, *i.e.*, levels that reduce the pO_2 levels to below 132 torr (ACGIH, 2008; NIOSH 1980) to create an exposure atmosphere that does not meet the minimum requirement of 19.5% oxygen at sea level to adequately support human respiration (NIOSH 1987; McManus, 1999). Asphyxiant concentrations of these gases would likely be above the lower explosive limit (LEL) of any petroleum gas stream in which they were found, consequently the fire and explosion hazards of the stream would outweigh any chemical hazards associated with these inorganic constituents.

7.1 Acute Toxicity

Benzene
An acute inhalation toxicity test was conducted by a method which approximates OECD Test Guideline, 403 but females only were tested. Groups of 10 female rats were exposed to benzene via inhalation for hour hours, then observed for 2 weeks following exposure. Animals dying during exposure and those killed at end of study subjected to necropsy. The LC50 value was reported as 13,700 ppm (converts to 44.7 mg/l) with 95% confidence limits of 13,050-14,480 ppm (converts 42.5 – 46.9 mg/l). Animals which survived the first 24 hours after exposure survived to the end of the 14 day observation period. Death appeared to be caused by a depression of the CNS. These animals had increased lung and liver weights, lung and liver congestion (increase in number of red blood cells and an increased number of vacuolated hepatocytes in the liver) (Drew and Fout, 1974).

Four hour (female Sprague-Dawley rat) LC50 = 13,700 ppm

1,3-Butadiene
The four-hour LC_{50} in rats and two-hour LC_{50} in mice were determined in a non-guideline study. The objective of study was to determine hydrocarbon concentrations in various tissues at lethal exposure concentrations. Animals were not observed after exposure and no clinical observations were reported. The rat LC50 (4 hour) = 129,000 ppm with 95% confidence limits of 99,126-167,473 ppm. The mouse LC50 (2 hour) = 122,000 ppm with 95% confidence limits of 99,126-167,473 ppm (Shugaev, 1969)

Four hour (rat) LC50 = 129,000 ppm

C1 – C4 Hydrocarbons
The acute toxicity of 2-butene was evaluated in an OECD Limit Test in Wistar rats. Groups of five male and five females were exposed to 10,000 ppm (23.1 g/m^3) of 2-butene (racemic mixture: 95% purity, 42.4% *cis*, 55.3% *trans*) or filtered air for four hours. Chamber concentrations were monitored by FID. Rats were then housed individually for 14 days of observation. Body weights were measured prior to exposure and on post-exposure days 7 and 14. Clinical signs were evaluated during exposure and daily thereafter. At day 14 animals were euthanized for macroscopic evaluation. No mortality was observed during the study. Restlessness was observed during and after exposure on the first day. No signs of clinical toxicity were observed for the remainder of the 14 day observation period. Body weights and gross pathology was comparable to control animals. The LC50 was greater than 10,000 ppm (Arts, 1992). In selecting 2-butene to represent the acute toxicity of the C1 – C4 HC fraction, the entire C1-C4 HC fraction concentration is assumed to be 100% 2-butene for purposes of calculating C1 – C4 HC acute toxicity ranges for each petroleum hydrocarbon gas.

Four hour (male and female Wistar rat) LC50 > 10,000 ppm (highest dose tested)

C5 – C6 Light End Naphtha Hydrocarbons
Light alkylate naphtha (API 83-19; CAS #64741-66-8; approx 100% paraffinic) is not acutely toxic. A group of 5 male and 5 female rats were exposed by whole body inhalation to API 83-19 at a nominal concentration of 5mg/l for 4 hours. This was achieved by total volatilization of the test material and appropriate dilution with air. After the 4 hour exposure the rats were observed twice daily for mortality. The animals were weighed prior to exposure and again on days 7 and 14 post exposure. On day 14 all surviving animals were killed by exsanguination following sodium pentobarbital anesthesia. For all animals, including those found dead during the study, the lungs were removed, fixed and examined histologically. The mean analytical and nominal exposure concentrations were 5.04 ± 0.74 and 6.31 mg/l respectively. All animals survived the study but exhibited languid behavior and a hunched appearance during the exposure. Female body weights were decreased at day 15 but this was attributed to pre-necropsy fasting. At necropsy there were no remarkable findings and histopathology of the lungs was normal (API, 1987a).
Light catalytic cracked naphtha (API 83-20; CAS #64741-55-5, approx. 46% olefinic) is not acutely toxic. A group of 5 male and 5 female rats were exposed by whole body inhalation to API 83-20 at a nominal concentration of 5 mg/l for 4 hours. After the 4 hour exposure the rats were observed twice daily for mortality. The animals were weighed prior to exposure and again on days 7 and 14 post exposure. On day 14 all surviving animals were killed and subjected to a gross post-mortem examination. For all animals, including those found dead during the study, the lungs were removed, fixed and examined histologically The mean analytical exposure concentration was measured and found to be 5.28 ±0.55 mgL. Gravimetric samples, collected on glass fiber filters suggested little or no aerosol in the chamber. Most animals exhibited languid behavior and squinted eyes during the second hour of the exposure. Polypnea was observed in all animals when removed from the chamber at the one hour post exposure observation period. Rhinorrhea was exhibited by two animals on day two of the test. All animals appeared normal subsequently and there were no mortalities during the study. With the exception of one animal (female) all animals had body weights that were considered unremarkable. There were no remarkable gross or microscopic findings (API, 1987b).
Sweetened naphtha (API 81-08, CAS #64741-87-3, approx. 21% naphthenics) is not acutely toxic. A group of 5 male and 5 female rats were exposed by whole body inhalation to API 81-08 at a nominal concentration of 5mg/l for 4 hours. After the 4 hour exposure the rats were observed twice daily for mortality. The animals were weighed prior to exposure and again on days 7 and 14 post exposure. On day 14 all surviving animals were killed by exsanguination following sodium pentobarbital anesthesia and were subjected to a full necropsy. For all animals, including those found dead during the study the lungs were removed, fixed and examined histologically. The actual chamber concentrations were found to be 5.2 mg/l. No deaths occurred during the study. There were no unusual pharmacotoxic signs or behavior observed in the control animals. There was however, a slight incidence of nasal discharge (2/5 males and 1/5 females) during the exposure period but none during the following 14 day observation period. The body weight gains for the males exposed to API 81-08 was considered normal but the female body weight gains were marginally less than those of the controls on day 14 post exposure (8.2% compared to 13.8% increase over pre-exposure body weight). No significant macro- or microscopic changes were observed that were considered to be treatment related (API, 1987c).

Full range catalytic reformed naphtha (API 83-05, CAS #68955-35-1, approx. 63% aromatics) is not acutely toxic. A group of 5 male and 5 female rats were exposed by whole body inhalation to API 83-05 at a nominal concentration of 5 mg/l for 4 hours. After the 4 hour exposure the rats were observed twice daily for mortality. The animals were weighed prior to exposure and again on days 7 and 14 post exposure. On day 14 all surviving animals were killed by exsanguination following methoxyflurane anesthesia and were subjected to a full necropsy. For all animals, including those found dead during the study the lungs were removed, fixed and examined histologically. The exposure chamber TWA concentration was determined to be 5.22 ± 0.14 mg/l. No animal died during the study and no clinical signs of systemic toxicity were observed. There were no significant gross observations at necropsy and no histological changes were observed in the lungs. The 4 hour LC_{50} was therefore greater than 5.22 mg/l (API, 1984).

Results of testing naphtha blending streams for acute toxicity indicate that these materials demonstrate consistently low toxicity by the inhalation [rat LC50 >5g/m^3] exposure route. Weight of the evidence indicates that the C5 – C6 light naphtha hydrocarbon inhalation acute toxicity LC50 is > 5g/m^3 (~1063 ppm).

Four hour (rat) LC_{50} > 1063 ppm

Acute Toxicity Conclusions

No acute toxicity LC50 values have been derived for the C1 – C4 and C5 – C6 hydrocarbon fractions because no mortality was observed at the highest exposure levels tested (~ 5 mg/l) for these petroleum hydrocarbon gas constituents. The order of acute toxicity of petroleum hydrocarbon gas constituents from most to least toxic is[3]:

C5 – C6 HCs (LC50 > 1063 ppm) > C1 – C4 HCs (LC50 > 10,000 ppm) > benzene (LC50 = 13,700 ppm) > butadiene (LC50 = 129,000 ppm) > asphyxiant gases (hydrogen, carbon dioxide, nitrogen)

7.2 Repeated-Dose Toxicity

Benzene
Male CD-1 mice (11–12/group) were exposed for 6 hours/day, 5 days/week to concentrations of 0 or 10 ppm (0 or 32 mg/m^3) benzene for 10 weeks or to 0 or 300 ppm (0 or 958 mg/m^3) for 26 weeks (Green et al., 1981a,b). On the day of the last exposure, samples (pooled from groups of 3–4 mice) were obtained from the peripheral blood, bone marrow, and spleen to evaluate hematologic and hematopoietic cells. In mice exposed to 10 ppm (32 mg/m^3), no adverse effects were observed with respect to mortality, body weight, or cells in the peripheral blood or bone marrow. Spleen weight, total nucleated cells per spleen, and nucleated RBCs per spleen were significantly increased ($p<0.05$) in mice exposed to 10 ppm (32 mg/m^3). Mice exposed to 300 ppm (958 mg/m^3) had the following significant ($p<0.05$) changes: increased mortality rate; decreased numbers of lymphocytes and RBCs in peripheral blood; decreased granulocyte/macrophage progenitor cells in bone marrow; decreased spleen weight and numbers of lymphocytes; multipotential hematopoietic stem cells and committed granulocyte/macrophage progenitor cells in the spleen; and increased incidence of atypical cell morphology in the peripheral blood, bone marrow, and spleen. These studies identify a LOAEL ≤ 10 ppm (32 mg/m^3) for slight hematopoietic effects in mice exposed to benzene for 10 weeks.

LOAEL (mice) ≤ 10 ppm (lowest dose tested)

1,3-Butadiene
In considering the toxicity of 1,3-butadiene, it is important to determine the appropriate animal model for use in hazard characterization. It is generally agreed that butadiene produces toxicity when it is metabolized to its reactive metabolites after animals are exposed to butadiene. However, there are differences in metabolism amongst species. The basis of the species differences between rats and mice may be related to the greater production of toxic

[3] ranking is not precise since several values (*i.e.* LC50 values expressed as 'greater than') were the highest dose tested

intermediates and a lower capacity for detoxification of these intermediates (USEPA, 2002a). The metabolism of 1,3-butadiene and the toxicity of its reactive epoxide metabolites has been well studied. 1,3-Butadiene is first metabolized to 1,2-epoxy-3-butene (EB), a process that is primarily associated with cytochrome P450 (CYP) 2E1, but can also be accomplished by additional isoforms including CYP 2A6 and 4B1. This electrophilic metabolite can be detoxified by conjugation with glutathione and subsequent excretion in the urine as urinary metabolites 1-hydroxy-2-(N-acetylcysteinyl)-3-butene and 2-hydroxy-1-(N-acetylcysteinyl)-3-butene (collectively known as M2 metabolite). It can also undergo hydrolysis by epoxide hydrolase (EH) to form 3-butene-1,2-diol (butene-diol). Butene-diol can also be conjugated with glutathione and subsequently excreted in the urine as urinary 1,2-dihydroxy-4-(N-acetylcysteinyl)-butane (M1 metabolite). It can be further oxidized by cytochrome P450 to the 1,2-dihydroxy-3,4-epoxybutane (EBD). An alternative pathway for the metabolism of EB is oxidation to the 1,2:3,4-diepoxybutane (DEB) which can be further hydrolyzed to EBD or conjugated by glutathione. This series of epoxidation and detoxification steps generates three electrophilic metabolites: EB, DEB, and EBD (Himmelstein *et al.,* 1997; TCEQ, 2008). *In vitro* studies have shown that mice are 2- and 10-fold more efficient than rats in oxidizing 1,3-butadiene to EB (Schmidt and Loeser, 1985; Csanady *et al.*, 1992). The second oxidation step to DEB could be mediated *in vitro* only by mouse liver microsomes (Csanady *et al.*, 1992). Cochrane and Skopek (1994) have shown that DEB is 100 times more mutagenic than EB and 200 times more mutagenic than EBD in human lymphocytes. The extent to which DEB is produced and reaches target tissues will play a role in the toxicity (Kligerman and Yu 2007). Mice form more DEB than rats or humans whereas EBD is more readily formed in humans than in rats (Slikker *et al.* 2004; Swenberg *et al.* 2007). *In vivo* studies of 1,3-butadiene metabolism in mice and rats have also shown large interspecies differences. M1/(M1 + M2) metabolite ratios in urine for mice and rats exposed to 1,3-butadiene by inhalation indicate that conjugation detoxification predominates in mice but that hydrolysis is more important in rats (Henderson *et al.*, 1996). In summary, mice are more efficient in oxidation of 1,3-butadiene to electrophilic metabolites (especially to DEB), while rats are more efficient in hydrolytic detoxification (TCEQ, 2008). The existing metabolism data suggest that metabolism in humans appears to be more like metabolism in rats than in mice (ACC, 2004). Based upon this brief summary, and the more detailed information referenced, rat data will be used to estimate the 1,3-butadiene component for toxicities associated with Petroleum Hydrocarbon Gases Category Member repeated-dose, developmental, and reproductive hazards.

In an assessment of carcinogenic potential, three groups (110 male/110 female per group) of Sprague-Dawley rats were chamber-exposed to atmospheres of 0, 1000, and 8000 ppm 1,3-butadiene for two years. Control groups were exposed to clean air only. At 52 weeks, 10 males and 10 females from all groups were killed. The remaining animals were sacrificed when survival was approximately 20-25% (105 weeks for females and 111 weeks for males). The exposure was 6 hrs/day, 5days/wk. All animals were observed twice daily, before and after exposure, and a detailed observation was performed at weekly intervals. Individual body weights were recorded weekly up to week 13, then every 2 weeks to week 52 and monthly thereafter. Clinical chemistries, neuromuscular function and detailed post-mortem examinations were performed at the time of sacrifice. Analysis of the survival data, subcutaneous masses, lesions/tumor incidences was performed using a variety of statistical methods; body weights, clinical laboratory data, and organ weights were analyzed by using analysis of variance and Student's t-test.

Clinical signs that appeared to be related to treatment were seen in the second until the fifth month of exposure. Minor, treatment-related clinical signs of toxicity – wet and ruffled fur together with slight limb weakness or incoordination following dosing on the first day of the 5-day schedule – were seen between 2 and 5 months of treatment in animals at 8000 ppm. There were no effects on hematology, blood chemistry, urine analysis, and neuromuscular function that could be associated with treatment with 1,3-butadiene. Changes in clinical condition, suppression of body weight gain, reduced survival and increases in certain organ weights and in both common and uncommon tumor types occurred at 8000 ppm. At 8000 ppm, males had statistically significantly increased kidney, heart, lung and spleen weights, with associated nephrosis of the kidney and focal metaplasia in the lung. At the end of the study, statistically significant increases were seen in liver weight in all exposure groups, but there was no associated pathology. For both sexes, the LOAEL = 8000 ppm and the NOAEL = 1000 ppm (Owen and Glaister, 1990).

LOAEL (male and female Sprague Dawley rats) = 8,000 ppm
NOAEL (male and female Sprague Dawley rats) = 1,000 ppm

C1 – C4 Hydrocarbons

The repeated dose toxicity of a racemic mixture of 2-butene (cis and trans, 95% purity) was assessed in an OECD 422 Combined Repeated Dose Toxicity with the Reproductive/Developmental Toxicity Screening Test. Twelve male and 12 female Wistar rats per group were exposed to 0, 2500 or 5000 ppm 2-butene for 6 hours/day, 7 days/week. Males were exposed for 39 to 46 days; females were exposed two weeks prior to mating, through mating, and to gestation day 19. Body weights and food consumption were recorded. At study termination, hematology and clinical chemistry analyses were conducted on blood, gross necropsies were conducted, organs weights were recorded and tissues processed for microscopic evaluation. Tissues from control and high dose groups, only, were evaluated microscopically. Body weight change was lower for male rats in the first and fourth weeks of exposure in the 2500 ppm group and in the first week in the 5000 ppm group. Female body weights were reduced in the 2500 ppm group at 14 days of exposure and the 5000 ppm group at 7 and 14 days of exposure. Female body weights were comparable during mating and gestation, but were reduced in the 5000 ppm group on lactation day 1. Male rats in both exposure groups had increased total white cell and lymphocyte counts, however there was no dose-response and counts were within historical control range. A decrease in plasma calcium concentration was observed in high dose males. No other adverse treatment related effected were observed. The repeated-dose NOAEL for both sexes was 2500 ppm. The repeated-dose LOAEL for both sexes was 5000 ppm (Waalkens-Grendsen and Arts, 1992). In selecting 2-butene to represent the repeated-dose toxicity of the C1 – C4 HC fraction, the toxicity of the entire C1-C4 HC fraction in each petroleum hydrocarbon gas is assumed to be equivalent to that of 100% 2-butene for purposes of calculating C1 – C4 HC repeated-dose toxicity ranges for each petroleum hydrocarbon gas.

LOAEL (male and female Wistar rat repeat dose) = 5000 ppm
NOAEL (male and female Wistar rat repeat dose) = 2500 ppm

C5 – C6 Light End Naphtha Hydrocarbons
To assess the potential for repeated dose toxicity of the C5 – C6 Light End Naphtha Hydrocarbons, Baseline Gasoline Vapor Condensate [BGVC], a 20% light fraction of a whole unleaded gasoline sample was evaluated in a 13- week inhalation study according to OPPTS 870.3465. This test material was a representative evaporative emission tested under the USEPA 211(b) Fuels and Fuel Additives Health Effects Testing Program (1994a, 1998). BGVC was administered to Sprague Dawley rats (10/sex/group) at target concentrations of 0, 2000, 10000, and 20000mg/m^3 (actual concentrations 0, 2050, 10,153 and 20,324 mg/m^3) 6hr/day, 5 days/week for 13 weeks. Additional groups of control and high dose rats (10/sex/group) were also exposed and retained untreated for an additional 4- week recovery period (API, 2005a). Clinical signs, body weights and body weight changes, and food consumption were recorded throughout the study. Opthalmoscopic evaluations were performed pretest and at exposure termination. Hematology, coagulation and clinical chemistry parameters were measured at week 4 and week 13. Neurobehavioral evaluations of motor activity and functional activity [FOB] were performed on 10 rats/sex/group pretest and during weeks 3, 7, and 12 of exposure according to OPPTS 870.6200. After 13 weeks exposure surviving rats were sacrificed except for those intended to assess recovery; animals in the recovery groups were sacrificed at week 17 following 4 weeks without treatment. Fourteen selected organs were weighed. Histopathology examination was performed on 31 tissues from rats in the control and high dose groups and on kidneys from rats in all groups. Five rats/sex/group were perfused for neuropathological evaluation and sections of brain, eye, spinal cord, peripheral nerves and ganglia were examined microscopically. Satellite groups of animals were exposed to BGVC with the subchronic rats for immunotoxicology, genetic toxicity and glial fibrillary acidic protein (GFAP) analyses. The genetic toxicology studies are presented in Section 7.1.4 of this document. The immunotoxicology and GFAP report details are provided in robust summaries, and are not considered further here other than to state that BGVC did not produce significant effects in the parameters measured in these two satellite studies.

Test animals were generally unremarkable in exposure chambers and during non-exposure periods except for a slight increase in red nasal discharge seen in rats exposed to 20,324 mg/m^3 during 13 weeks of exposure but not during recovery. No adverse effects were induced by BGVC on ophthalmology, body weights, feed consumption or blood chemistry parameters. No toxicologically significant changes were observed in organ weights although male absolute and relative kidney weights were slightly elevated at the mid and high dose levels. Gross abnormalities were not seen at terminal sacrifice. Dose related microscopic findings included eosinophilic material in the nasolacrimal ducts in high dose rats consistent with reported red nasal discharge and renal histopathologic changes in kidneys of all treated male rats. These renal changes were consistent with alpha 2-microglobulin mediated

nephropathy, a species and sex-specific change not considered relevant to human health (USEPA, 1991). Kidneys of male rats exposed to BGVC 20,324 mg/m^3 for 13 weeks and then held for an additional 4 weeks to assess recovery had nearly complete resolution of these changes. BGVC did not cause adverse neurobehavioral or neuropathologic effects. The systemic LOAEL [excluding male kidney effects] = 2,0324 mg/m^3 (~ 6,625 ppm) and NOAEL = 10,153mg/m^3 (~ 3,310 ppm). NOAEL for neurotoxicology = 20,324 mg/m^3 (~ 6,625 ppm) (API, 2005a).

LOAEL (male and female Sprague Dawley rats) = 6,625 ppm
NOAEL (male and female Sprague Dawley rats) = 3,310 ppm

Repeated-Dose Conclusions

With the exception of the asphyxiant gases, repeated dose toxicity has been observed in individual selected petroleum hydrocarbon gas constituents. Based upon LOAEL values, the order of order of repeated-dose toxicity of these constituents from most toxic to the least toxic is:

Benzene (LOAEL ≤ 10 ppm) >C1 – C4 HCs (LOAEL = 5,000 ppm; assumed to be 100% 2-butene) > C5 – C6 HCs (LOAEL = 6,625 ppm) > butadiene (LOAEL = 8,000 ppm) > asphyxiant gases (hydrogen, carbon dioxide, nitrogen)

7.3 In Vitro Genetic Toxicity

Benzene
The *in vitro* potential mutagenic activity of benzene was investigated by the Ames test using 4 strains of bacteria *Salmonella typhimurium*: TA 1535, TA 100, TA 104 and TA 98. This test enables the detection of base-pair substitution and frameshift mutagens. Tests were also conducted on benzene and its following metabolites (additional bacterial strains were added, i.e., TA 102 and TA 97): benzene oxide, phenol, hydroquinone, 4,4'-dihydroxybiphenyl, 2,2'-dihydroxy-biphenyl, quinone, trans-benzene-1,2-dihydrodiol , catechol and 1,2,4-trihydroxybenzene. Duroquinone, and anti-benzene-diol-epoxide, syn-benzene-diol-epoxide and 1,2,3-trihydroxybenzene were also included. *S. typhimurium* was exposed to benzene vapor in desiccators to allow for longer exposure periods (as opposed to plate incorporation method). The exposure atmospheric concentrations were 0, 3, 6, 15, 30, 100, 150, 300, 1000 ppm. Each assay was carried out both in the absence and in the presence of a metabolic activation system, NADPH-fortified, S9 mix derived from Aroclor 1254 induced rat or mouse liver homogenate (17 mg/plate). The test compound, bacteria and S9 fractions or buffer were preincubated for 20 min at 37°C and then added to minimal agar plates. After incubation for 3 days, the colonies were counted. A response was considered to be positive response if the number of colonies was > 2 times the control value. A cytotoxic concentration was not identified. Benzene was found to be mutagenic in the presence but not the absence of S9. The most responsive strain was TA 1535. A 2-fold increase in the number of mutants above control was observed even at a benzene concentration as low as 10 ppm. However, further increases in the concentration had only a modest effect. The maximal mutant number was about 3-fold the values for the control plates. Similar effects were then seen over a wide concentration range. In this same strain (TA 1535), the metabolites trans-benzene-1,2-dihydrodiol in the presence of S9 and anti-benzene-diol-epoxide and syn-benzene-diol-epoxide in the absence of S9 induced mutations. No other metabolite including catechol to which trans-benzene-1,2-dihydrodiol is converted by cytosolic dihydrodiol dehydrogenase, gave a positive result in strain TA1535. Mutagenic responses, some of them weak, were noted in other strains treated with 1,2,3-trihydroxybenzene, 1,2,4-trihydroxybenzene, catechol, quinine, hydroquinone, syn-benzene-diol-epoxide and anti-benzene-diol-epoxide. Benzene vapor was mutagenic in *S. typhimurium* TA 1535 in the presence but not the absence of S9 (Glatt *et al.*, 1989).

Positive for bacterial mutagenicity

Benzene was tested in a Sister Chromatid Exchange (SCE)assay in human peripheral lymocytes with or without metabolic activation system. Induction of SCEs is not a genotoxic event, per se, since no genetic material is lost and gene pairing of alleles remains intact. However, it does indicate an interaction with the DNA, which may or may not be confirmed as genotoxic in assays specifically designed to test for genotoxicity. Metabolic activation was

provided by rat liver microsomal fraction (S9) of rats induced with Aroclor 1254. The test material was tested at 0, 16, 78, and 391 mg/L. Heparinized whole blood was obtained from healthy adult men. Benzene was dissolved in serum-free culture medium and the metabolic activation system (S9 mix derived from Aroclor-induced rat liver) and incubated in a flask for 2 hours. The flask was agitated to ensure even distribution of active metabolites among the cells. After incubation, the cells were washed, resuspended in the same medium and incubated further. SCEs were analyzed in 35 consecutive second-division cells for each point. 200 metaphase cells were scored to determine the percentage of cells in X1, X2, and X3+ divisions. An increased number of SCEs were found in cultures treated in the presence of 10% S9 mix. In the absence of S9 and at S9 concentrations of 1 or 90% no increase in the frequency of SCEs was noted. Ten % S9 mix was the optimal concentration for the induction of SCEs. When the cells were exposed to benzene concentrations of 2 X 10-4, 1X 10-3 and 5 X 10-3M (approximately 16, 78 and 391 mg/L), a dose-related increase in SCEs was seen when the appropriate activation concentration was used. It was hypothesized that S9 mix at 10-30% converted benzene into active forms that were cytotoxic and delayed cell turnover times. Further examination suggested that the metabolites responsible for cell division delay may be different from those which induce SCE. The addition of glutathione to the culture caused a dose-dependent decrease in SCEs in cells exposed to benzene and S9 mix. The addition of glutathione also completely prevented the induction of SCEs by catechol and hydroquinone, two major phenolic metabolites of benzene and potent inducers of SCEs. Benzene induced SCEs in a dose-dependent manner the presence but not the absence of the optimal amount of S9 (Morimoto, 1983).

Positive for induction of non-bacterial chromosomal SCEs

1,3-Butadiene
The *in vitro* potential mutagenic activity of 1,3-butadiene vapor was investigated in a bacterial mutagenicity assay using 4 strains of bacteria *Salmonella typhimurium*: TA97, TA98, TA100, and TA1535. This test enables the detection of base-pair substitution and frameshift mutagens. The test substance was tested in two independent assays. Each assay was carried out both in the absence and in the presence of a metabolic activation system (Arochlor 1254-induced and uninduced rat and mouse S9, and human S9) at a level of 0.8 mg/ protein/plate. Test material concentrations were 0, 30, 40, 50, and 60% 1,3-butadiene in air. Concentrations of 1,3-butadiene gas were metered into specially constructed treatment chambers holding the agar plates overlaid with the bacteria and activation system. Actual gas concentrations were determined by gas chromatography before and after the 48 hour exposure period. Different treatment chambers were used for each activation system and for the non-activated treatment. 1,3-Butadiene (BD) induced revertants only in strain TA1535. Mouse S9 showed slightly higher activity than the uninduced rat or human S9 at 30% 1,3-butadiene in air. At concentrations greater than 30%, the number of revertants decreased in the presence of rat or human S9. Results from the human S9-activated treatments did not differ substantially from those of the non-activated treatments. Arochlor 1254-induced rat S9 gave similar results as mouse S9 (uninduced). Since the response was weak, the S9 concentration was increased from 0.8 mg/plate to 4.0 mg/plate. Increasing the concentration of Arochlor 1254-induced rat S9 had no effect on the number of revertants; slightly more revertants were observed using 4.0 than 0.8 mg/plate of uninduced rat S9. *Salmonella typhimurium* reverse gene mutation (Ames) tests of 1,3-butadiene using strains TA1535, TA97, TA98, and TA100 and employing rat, mouse, and human liver S9 metabolic systems were barely 2-fold above background only in strain TA1535 at 30% 1,3-butadiene in air with induced and uninduced rat S9 and mouse S9 (uninduced). In general, 1,3-butadiene was a weak *in vitro* genotoxin (Arce, 1990).

Positive for bacterial mutagenicity

1,3- Butadiene (BD), and BD metabolites monoepoxybutene and diepoxybutane, were tested in a Sister Chromatid Exchange (SCE) assay in Chinese Hamster Ovary (CHO) cells with or without metabolic activation system. Induction of SCEs is not a genotoxic event, per se, since no genetic material is lost and gene pairing of alleles remains intact. However, it does indicate an interaction with the DNA, which may or may not be confirmed as genotoxic in assays specifically designed to test for genotoxicity. Metabolic activation was provided by rat liver microsomal fraction (S9) of rats induced with Aroclor 1254. Appropriate positive and solvent controls were evaluated concurrently with test samples. The test chemicals were added after 24 hr of incubation, and then pulse treated. The duration of the pulse treatment was 4 hr in serum-free bromodeoxyuridine (BudR)-free medium, in the presence or absence of S9 mix. The cultures were rinsed and incubated for the next 24 hr with BudR added. The

concentrations of chemicals, used in experiments were as follows: 1,3-butadiene, 25, 50, 100 and 200 μM; monoepoxybutene, 1, 5, 25, 50, 100 and 200 μM; diepoxybutane, 0.1, 1, 50 and 100 μM. Duplicate cultures were set up for each treatment. SCEs were stained and scored from the second-division cells. 60 cells per treatment point were analyzed and the statistical significances were calculated using a one-tailed Student's t-test. The cytotoxic concentrations of test material were >200 μM with and without metabolic activation. In the absence of S9 mix no increase of SCEs was observed even at the highest concentration of 1.3-butadiene. In the presence of S9, a slight dose response was observed. Both metabolites of 1.3-butadiene (monoepoxybutene and diepoxybutane) demonstrated a very clear dose-dependent increase in SCEs, both with and without S9 mix. 1,3-Butadiene is weakly positive for inducing SCEs in cultured CHO cells with a metabolic activation system (Sasiadek *et al.,* 1991).

Positive for induction of non-bacterial chromosomal SCEs

C1 – C4 Hydrocarbons
Hydrocarbons in the C1 – C4 range were not mutagenic in several *in vitro* bacterial cell test systems. C1 – C4 hydrocarbons that have been tested include methane, n-propane, n-butane, isobutane, liquefied petroleum gas (primarily butane and propane), ethylene, propylene, butylene, isobulyene and acetylene. Please see Appendix 4 for experimental systems and references. A study on 2-butene was selected for the C1 – C4 hydrocarbon bacterial mutagenicity key study.

The *in vitro* potential mutagenic activity of 2-butene (mixed isomers; 42.4% cis, 55.3% trans) was evaluated in an OECD Guideline #471 bacterial mutagenicity assay using 4 strains of *Salmonella typhimurium*: TA 1535, TA 1537, TA 100, and TA 98. Activation system: Sprague Dawley male rat liver (S9 fraction). 10% S9 fraction in S9 mix, (0.05 ml S9 fraction/plate) Aroclor 1254 induced; 500 mg/kg single ip injection 5 days before sacrifice. A 0.1 ml aliquot of *Salmonella*, 2.0 ml molten top agar, 0.5 ml S9 mix or 0.5 ml pH 7.4 phosphate buffer were mixed in a test tube and poured on minimal agar plates (3 plates/ conc./± S9 mix). Atmospheres of varying concentrations (0.0, 10, 20, 40, 60, 80%) were generated by mixing 2-butene with clean dry air, using precalibrated gas flow meters as gas flow indicators. Mixtures passed into 10L stainless steel containers holding Salmonella plates with triple vented lids. Concentrations were selected based on a preliminary range finding test with TA100 ± S9; dose-related reduction in frequency of revertant colonies and reduced growth of background lawn observed at 80, 100%. Containers holding 3 stacks of 8 plates each were flushed with appropriate concentrations of 2-butene for 5 minutes to allow system to equilibrate; containers were incubated at 37 C^{o} for 48 hrs and numbers of revertant colonies counted. Analytical determinations were performed by GC on syringe samples of test atmospheres at the differing concentrations. Positive control compounds were: -S9, N-ethyl-N' nitro-N-nitrosoguanidine, 3 μg/plate for TA100, 5 μg/plate for TA1535; 9 amino acridine, 80 μg/plate for TA1537; 4-Nitroquinoline-1-oxide, 0.2 μg/plate for TA98; +S9, 2-aminoanthracene 2 μg/plate for TA1535; benzo(a)pyrene 5 μg/plate for all other strains. Vinyl chloride (50% concentration) was the gaseous positive control for all strains; negative control was clean dry air. The complete experiment was repeated using fresh bacterial cultures, test material and control solutions. Criteria for positive response were induction of dose-related and statistically significant increases in mutation rate in one or more strain of bacteria ± S9 in both experiments at subtoxic doses. Toxicity was exhibited in all strains at 80% butene-2. In experiment 2, slight toxicity also occurred at 60%. No significant increases in number of revertant colonies of any strain of bacteria were observed at any dose concentration ± S9. Controls performed appropriately. 2-Butene was not mutagenic in the *Salmonella typhimurium* assay with or without metabolic activation (Thompson, 1992).

Negative for *in vitro* bacterial mutagenicity

Hydrocarbons in the C1 – C4 range are not mutagenic in several *in vitro* mammalian cell test systems. C1 – C4 hydrocarbons that have been tested include ethylene, butylene, and propylene. Please see Appendix 4 for experimental systems and references. A study on 2-butene was selected for the C1 – C4 hydrocarbon bacterial mutagenicity key study.

2-Butene (mixed isomers; 42.4% cis, 55.3% trans) was evaluated in an OECD Guideline #473 chromosome aberration assay in Sprague Dawley rat primary blood lymphocyte cultures. Metabolic activation system: Sprague Dawley male rat liver (S9 fraction) -20% S9 fraction in S9 mix, (10% v/v S-9 mix/flask) Aroclor 1254 induced; 500 mg/kg single ip injection 5 days before sacrifice. Atmospheres of varying concentrations of butene (0.0, 10, 20, 40,

50, 60, 80, 100%) were generated by mixing 2-butene with clean dry air, using precalibrated gas flow meters as gas flow indicators. Mixtures passed through culture flasks for sufficient time (time not specified) to allow equilibration of the system. Analytical determinations were performed by GC on syringe samples of test atmospheres at representative concentrations. Blood samples were drawn from male rats (Sprague Dawley -CD-1, ages 8-20 wks. from CharlesRiver UK); cells were grown in RPMI medium supplemented with 10% fetal calf serum, 25 mM Hepes and antibiotics, at 37 degrees C in a humidified atmosphere of 5% carbon dioxide in air. Duplicate cultures were incubated for 48 hrs, then transferred to tubes, centrifuged and culture medium drawn off and saved. Cells were resuspended in flasks, in fresh culture medium with or without S9 metabolic activation mix and exposed to appropriate concentrations of 2-butene or control materials. Flasks were sealed and shaken to maximize cell exposure for 4 hrs +S9 or 20 hrs -S9. Cells exposed to 2-butene + S9 were resuspended after 4 hrs in original culture medium; one group was harvested at 20 hrs (16 hr recovery), the other at 30 hrs (26 hr recovery) after initiation of treatment; -S9 cultures were harvested after 20 full hours exposure to butene-2. Positive controls were ethyl methyl sulfonate (500 µg/ml) –S9, cyclophosphamide (4.2 µg/ml) +S9; gaseous control was vinyl chloride (50%) in 20 hr group –S9 and 30 hr group +S9. Negative control was clean, dry air. Frequency of cells with aberrations (± gaps) and frequency of polyploid cells (duplicate culture data pooled) were compared with concurrent vehicle control using Fisher's Exact Test. The cytotoxic concentrations of 2-butene were 50% and 80% with and without metabolic activation, respectively. Control compounds performed appropriately. 2-Butene did not induce significant dose-related increases in frequency of structural chromosome aberrations or polyploid cells at any concentration level at any harvest period either in the presence or absence of a liver enzyme metabolizing system. 2-Butene was not clastogenic to rat lymphocytes *in vitro* (Wright, 1992).

Negative for *in vitro* non-bacterial genotoxicity

C5 – C6 Light End Naphtha Hydrocarbons
Unleaded gasoline was tested in the Ames Microbial mutation assay in *Salmonella typhimurium* and *Saccharomyces cerevisiae* with and without metabolic activation from an Aroclor-induced rat liver homogenate mixture. *Salmonella* strains TA100, TA1535, TA1537, TA1538, TA98 and yeast strain D4 were employed. Based on preliminary cytotoxicity assays, concentrations of gasoline in dimethylsulfoxide were administered to all 5 *Salmonella* tester strains at doses of 0.375, 0.75, 1.5 and 3.0% and to yeast at doses of 0.625, 1.25, 2.5, and 5.0%. For plate assays, test material was added to cells in broth. The contents of the test tubes of broth plus test material were poured over selective agar plates. Plates were incubated at 37^0C for 48 hours, then removed from the incubator and revertant cells were counted. In the suspension tests, bacteria and yeast cultures were grown in complete broth. The cells were removed, washed and exposed to the test material. For the yeast cells exposure to gasoline was for 4 hours and bacterial cell exposure was for 1 hour. Aliquots of the cells were plated onto the appropriate complete media. After suitable incubation periods, the number of revertant colonies was counted. In the plate test**,** there was no increase in revertant colonies caused by exposure to gasoline at any concentration. The results in this assay were negative both with and without metabolic activation. In the suspension test without activation, slight increases were observed at the high dose levels with TA100, TA1537 and TA1538. However the responses were not sufficiently high to meet the criteria for positive responses. The increases with TA98 could not be reproduced in a repeat trial. In the suspension test with activation, scattered increases were found at one or more dose levels but were not reproducible in a repeat trial. Therefore, gasoline was not a mutagen in this test system. (API, 1977)

Negative for *in vitro* bacterial mutagenicity

Gasoline diluted in acetone, has been tested in a mouse lymphoma (L5178Y TK+/-) forward mutation assay. For the mutation assay the lymphoma cells were exposed for 5 hours to test material at concentrations ranging from 0.065 to 1.04 µl/ml, both with or without a metabolic activation mix (Aroclor-induced rat liver S-9 homogenate). After exposure to the test material, the cells were allowed to recover for 3 days and then cultures were selected for cloning and mutant selection. Surviving cell populations were determined by plating diluted aliquots in non-selective growth medium. A mutation index was derived by dividing the number of clones formed in the BUdR-containing selection medium by the number found in the same medium without BUdR. The ratio was then compared to that obtained from other dose levels and negative control values. Positive control compounds were ethyl methane sulfonate (EMS) for non-activated cultures and dimethylnitrosamine (DMN) for metabolically

activated cultures. Little toxicity was observed with the test material. All results for gasoline from the non-activation assay were negative. The results from the activation assay were also considered to be negative. There was an increase in the number of mutants at the 0.52 µl/ml concentration but this appeared to result from a slight increase in the number of viable clones. There was no trend indicating a dose-related response and therefore, the increases were not believed to be compound related. Gasoline was not mutagenic in this mammalian cell system. (API, 1977)

Negative for *in vitro* non-bacterial genotoxicity

In Vitro Genetic Toxicity Conclusion
The majority of the Petroleum Hydrocarbon Gases Category components are negative for *in vitro* genotoxicity. The exceptions are: benzene and 1,3-butadiene, which are genotoxic in bacterial and mammalian *in vitro* test systems.

7.4 In Vivo Genetic Toxicity

Benzene
Micronucleus assay and SCE
The induction of chromosomal effects under *in vivo* conditions after short term inhalation of benzene was evaluated in Sprague Dawley rats and DBA/2 mice in micronucleus and sister chromatid exchange (SCE) assays. Induction of SCEs is not a genotoxic event, per se, since no genetic material is lost and gene pairing of alleles remains intact. However, it does indicate an interaction with the DNA, which may or may not be confirmed as genotoxic in assays specifically designed to test for genotoxicity. Five male mice per treatment group were exposed for 6 hours to benzene vapors by inhalation at 0, 10, 100, or 1,000 ppm. Five male rats per treatment group were exposed to 0.1, 0.3, 1, 3, 10, or 30 ppm benzene for 6 hours. Air-exposed control groups of 10-20 male mice/rats were evaluated concurrently with the benzene-treated groups. Exposure chamber atmospheres were analyzed hourly for the top two benzene concentrations and two to three times per hour for the other doses. The animals were killed 18 hours after exposure and peripheral blood lymphocytes and femoral bone marrow samples were taken and slides prepared. The lymphocytes were cultured in the presence of liposaccharides or concanavalin-A to stimulate blastogenesis for SCE analysis. 5-Bromo-2-deoxyuridine was added 24 hours after culture initiation and the cultures harvested at 60 hrs (mice) or 52 hrs (rats) following a 4 hr demecolcine treatment. Two or three slides were prepared per animal for SCE analysis. Slides from five treated and three to five concurrent control animals were coded, combined, and randomized prior to analysis. Both parametric (Student t test) and nonparametric (Mann-Whitney U test) statistics were used to analyze the data. Polychromatic erythrocytes (PCEs) in the prepared bone marrow samples (one to four stained slides per animal) were assayed for micronuclei.One thousand - 2000 PCEs were analyzed from the bone marrow of each animal. One thousand nuclei and 100 metaphases were scored consecutively for mitotic index and cell cycle kinetics, respectively. A one-tailed Student's t test was used to compare the micronuclei frequencies in the benzene exposed animals to controls. In mice, all levels of benzene induced statistically significant, dose-related increases in SCE frequency in peripheral lymphocytes. Doubling of the spontaneous SCE frequency was achieved only at the highest dose tested (1000 ppm). In mouse bone marrow, all levels of benzene induced a statistically significant, dose-related increases in polychromatic erythrocytes containing micronuclei. At 1000 ppm, a 13.4 – fold increase from the control level was observed. In rats, 3, 10, and 30 ppm benzene caused dose dependent increases in the frequency of SCEs. In rat bone marrow, 1, 3, 10, and 30 ppm induced significant increases in the frequencies of micronuclei per 1000 polychromatic erythrocytes. It was concluded that short term exposures to benzene induced statistically significant increases in SCEs in lymphocytes and polychromatic erythrocytes (micronuclei) in rats and mice (Erexson, 1986).

Positive for *in vivo* genotoxicity

1,3-Butadiene
The genotoxic potential of nose-only inhalation exposure of butadiene to induce micronucleus formation in peripheral and bone marrow erythrocytes was determined in rats and mice. Twenty female CB6F1 mice (approximately 25g, 8-10 weeks old) and ten male Wistar rats (300-350g, 10 weeks old) per group were exposed for 5 days, 6 h/day to 0, 50, 200, or 500 ppm of 1,3-butadiene by inhalation. An additional high concentration group of mice was exposed to 1300 ppm. Exposure concentrations were monitored by infrared spectroscopy (rats) and gas chromatography (mice). The animals were sacrificed 1 day after the last exposure and smears of blood and bone

marrow erythrocytes were prepared and stained. In the rats, no effects on micronuclei frequencies were observed either in the peripheral blood or bone marrow at any exposure level. A slight toxic effect in rat bone marrow cells (decreased polychromatic/normochromatic ratio) was observed at the 500 ppm level. This effect was statistically significant at 500 ppm with the Student's t test, 2-tailed. An apparent decrease of the polychromatic to normochromatic ratio in a dose-dependent way was observed, but was not statistically significant with the linear regression test. In the mice, a clear dose-dependent increase in micronuclei frequency was observed in both blood and bone marrow cells at all exposure levels tested. 1,3-butadiene was active in inducing micronuclei in peripheral blood and bone marrow erythrocytes in mice at levels >50 ppm, but not in rats. The genotoxic effects observed in this study parallel the species differences observed in cancer studies (Autio, 1994).

Positive for *in vivo* genotoxicity

C1 – C4 Hydrocarbons
Hydrocarbons in the C1 – C4 range were not mutagenic in several *in vivo* micronuclei studies at concentrations up to 22,000 ppm. The C1 – C4 hydrocarbons that have been tested include liquified petroleum gas (primarily butane and propane), ethylene, propylene, butylene, and isobutylene. Please see Appendix 4 for experimental systems and references. The following mouse micronucleus assay on 1-butene is representative of the negative *in vivo* mutagenicity studies for the C1 – C4 HCs.

The potential of 1-butene to cause micronucleus formation was assessed using nose-only inhalation exposure in Swiss-Webster mice. 1-Butene was premixed with ambient air and introduced into inhalation chambers containing groups of mice (10 M, 10 F) at concentrations of 0, 1000, 9000,or 22,000 ppm 2 hrs/day for 2 days. One half of each group was killed on day 3 and the remainder on day 4 following exposure. One group (15 M, 15 F) exposed for one day to 22,000 ppm was killed on days 2, 3, 4 after treatment (5/sex/day). Test concentrations were monitored each day by gas chromatography. Positive control mice given cyclophosphamide (75 mg/kg) ip daily for 2 days were killed on day 3. Slides of bone marrow smears were prepared, stained with May-Grunewald/Giemsa stain and examined microscopically. For each mouse, 1000 polychromatic erythrocytes and all mature erythrocytes (normochromatic erythrocytes) were counted. Data collected included group mean body weights for each day, total polychromatic erythrocytes total normochromatic erythrocytes, polychromatic erythrocytes with micronuclei, and normochromatic erythrocytes with micronuclei. Values from treated groups for daily mean body weights, group means and std. dev. for polychromatic erythrocytes with micronuclei, and group mean ratios of polychromatic erythrocytes to normochromatic erythrocytes were calculated and compared with vehicle control values by Student's t-test. Positive response was indicated by statistically significant ($p<0.05$) increases in micronucleated polychromatic erythrocytes at any dose level with a dose related response evident. Results were considered equivocal if only one of these criteria was met. 1-Butene given by inhalation 2 hrs/day for 2 days to mice had no effect on the frequency of micronucleated erythrocytes in bone marrow. Under these test conditions, 1-butene did not induce chromosomal damage (Khan and Ward, 1985).

Negative for *in vivo* genotoxicity

C5 – C6 Light End Naphtha Hydrocarbons
Baseline Gasoline vapor condensate [BGVC], a 20% light fraction of a whole unleaded gasoline was tested in the rat micronucleus assay according to USEPA OPPTS 870.5395 as a satellite study to the 13 week inhalation study described in Section 7.1.2 Repeated Dose Toxicity. Sprague Dawley rats (5/sex/group) were exposed by whole body inhalation to target concentrations of 0, 2000, 10000, 20000 mg/m^3 (actual concentrations 0, 2050, 10,153 and 20,324 mg/m^3) BGVC for 4 weeks, 6hr/day, 5 days/week. A separate positive control group was treated with 40 mg/kg cyclophosphamide by intraperitoneal injection 24 hours prior to sacrifice. Rats were killed 24 hours after the 20th exposure and bone marrow from both femurs of each rat was prepared as smears on microscope slides. Slides were stained by the modified Feulgen method. One smear from each rat was examined for the presence of micronuclei in 2000 immature erythrocytes and cytotoxicity was determined by the ratio of immature erythrocytes in at least 1000 erythrocytes. The incidence of micronucleated mature erythrocytes was also recorded. BGVC did not cause statistically significant increases in micronucleated immature erythrocytes or micronucleated mature erythrocytes at any dose level. There was no cytotoxicity or a decrease in the proportion of immature erythrocytes observed. Baseline Gasoline Vapor Condensate did not induce cytogenetic damage in this test system. NOAEL ≥ 20324 mg/m^3. (API, 2005b)

BGVC was also tested with a separate satellite group for the induction of sister chromatid exchange [SCE- a non-SIDs endpoint], using an in vivo/in vitro protocol. Sprague Dawley rats (5/sex/group) were exposed by whole body inhalation to target concentrations of 0, 2000, 10000, 20000 mg/m^3 (actual concentrations 0, 2050, 10,153 and 20,324 mg/m^3) BGVC for 4 weeks, 6hr/day, 5 days/week. A separate positive control group was treated with 5mg/kg cyclophosphamide by intraperitoneal injection 24 hours prior to sacrifice. Rats were killed 24 hours after the 20th exposure. Blood (2-4ml) was collected from the abdominal aorta, cultured within 24 hours and incubated at 37^{0}C for 21 hours. Cells were then exposed to 5µg/ml bromodeoxyuridine. After 68 hours from culture initiation, 0.2 µg/ml colcimide was added to each culture flask to arrest cell division and incubation was continued for 4 hours. At 72 hours total elapsed culture time, cells were collected, washed and fixed. Slides were prepared for microscopic evaluation. A minimum of 25 second-division metaphases per animal was scored for SCE. At least 100 consecutive metaphases per animal were scored for the number of cells in 1st, 2nd, and 3rd division metaphase as an indicator of toxicity (cell cycle delay) and 1000 cells were scored for mitotic index per rat. Statistically significantly increased SCE frequency was observed at all 3 dose levels in females and at the 10153 and 20324 mg/m^3 levels for males. Increases in average generation time were also observed but no appreciable differences in mitotic indices were seen for any test group compared to controls. Although the SCE assay demonstrated interaction of BGVC and DNA, it was not considered definitive for clastogenic activity since no genetic material was unbalanced or lost, but rather was considered a biomarker of exposure. Negative results in a parallel micronucleus assay, which visualizes actual cytogenetic damage demonstrate that BGVC is not a clastogenic material (API, 2005c).

Negative for *in vivo* genotoxicity

In Vivo Genetic Toxicity Conclusions
The majority of the Petroleum Hydrocarbon Gases Category components are negative for in v*ivo* genotoxicity**.** The exceptions are benzene and 1,3-butadiene, which are genotoxic in *in* v*ivo* test systems**.**

7.5 Developmental Toxicity

Benzene
The developmental toxicity of benzene was evaluated in a series of three experiments. Female Swiss-Webster (Crl: CFW(SW)Br) mice (5-10 mice/concentration level) were exposed (0, 5, 10, or 20 ppm benzene, 6h/day, gestation days 6-15 in all experiments. In experiment 1, five benzene-exposed and five air-exposed pregnant mice were sacrificed on the 16th day of gestation, their uteri removed, and the number of live, dead, and resorbed fetuses recorded. Two male and two female fetuses were then randomly selected, weighed, and examined for any external gross morphological malformations. Peripheral blood samples were taken for red and white cell counts and for hemoglobin analysis. Livers were removed for enumeration of recognizable cells in the hematopoietic differentiating, proliferating pool (DPP). In experiment 2, five benzene-exposed and five air-exposed pregnant females were allowed to proceed through normal parturition. Two male and two female neonates were then randomly selected at 2 days of age and subjected to the same protocol as that described above with 16-day old fetuses. In experiment 3, five benzene-exposed and five air-exposed pregnant dams were allowed to proceed through normal parturition. At 6 weeks of age, one male and one female were randomly selected from each litter. Peripheral blood samples were obtained from tail veins for red and white cell counts and for hemoglobin analysis. These animals were then sacrificed and their spleens and femurs removed for enumeration of recognizable cells in the DPP. Peripheral and organ blood cell counts were determined, each benzene exposed animal having its own age-matched air control.

There was no evidence of maternal toxicity among dams exposed to any concentration of benzene tested as determined by maternal morbidity, mortality, or weight loss during the exposures. There was no evidence of non-hematopoietic toxicity among any of the fetal or neonatal progeny exposed *in utero* to any concentration of benzene studied. Litter sizes, male/female ratios, and body weights, as well as the numbers of dead, resorbed, or malformed fetuses, were all within control limits. In 2-day neonates, the 20 ppm exposure group showed significantly lower counts of late nucleated red cells and decreased counts of early nucleated red cells, whereas the numbers of blasts, dividing/nondividing granulocytes and lymphocytes were elevated. In 6-week old offspring, the 20 ppm exposure

group showed a slightly higher numbers of blasts, dividing/nondividing granulocytes and lymphocytes in comparison to their age-matched controls. *In utero* exposures to 20 ppm benzene induced persistent, enhanced production of granulopoietic elements in the hematopoietic systems of offspring. The maternal NOAEL was ≥ 20 ppm. The developmental LOAEL = 20 ppm, and the NOAEL = 10 ppm (Keller and Snyder, 1988).

LOAEL (mice) = 20 ppm
NOAEL (mice) = 10 ppm
Maternal systemic NOAEL ≥ 20 ppm

1,3-Butadiene
The developmental effects of 1,3-butadiene were evaluated in an OECD Guideline 414 teratogenicity study. Female Sprague Dawley rats were mated to unexposed males and exposed from days 6-15 of gestation to 0, 40, 200, or 1000 ppm of the test substance. Analytical chamber concentrations were measured by on-line gas chromatography. Body weights were recorded on gestation days 0, 6, 11, 16, and 20. Maternal animals were observed daily for mortality, morbidity, and signs of toxicity and examined for gross tissue abnormalities at necropsy (day 20). The uterus and placenta was removed and weighed; the number of implantation sites, resorptions, and live and dead fetuses were recorded. Live fetuses were weighed and subjected to external, visceral, and skeletal examinations. Approximately 50% of the fetal heads were sectioned and examined. Analysis of variance for body weights, number of resorptions, implants, live, dead or affected fetuses per litter was performed. Significant differences among the groups were also analyzed by Duncan's multiple range tests or arcsine transformation of the response proportion. Binary-response variables between groups were compared using chi-square or Fisher's exact test. The only toxicity observed was decreased body weight gains in the dams at 1000 ppm. The percentage of pregnant animals and number of litters with live fetuses were unaffected by treatment. There were no significant differences among the groups for number of live fetuses per litter, percent resorptions or malformations per litter, placental or fetal body weights, or sex ratio. There was no evidence of teratogenicity or adverse reproductive effects in any of the exposed groups. Based on decreased body weight gains, the maternal systemic toxicity LOAEL and NOAEL were 1000 ppm and 200 ppm, respectively. The NOAEL for developmental effects was ≥ 1000 ppm (Morrissey *et al.*, 1990).

Developmental (Sprague Dawley rats) ≥ 1000 ppm (highest dose tested)
Maternal systemic LOAEL = 1000 ppm
Maternal systemic NOAEL = 200 ppm

C1 – C4 Hydrocarbons
The developmental toxicity of a racemic mixture of 2-butene (cis and trans, 95% purity) was assessed an OECD 422 Combined Repeated Dose Toxicity with the Reproductive/Developmental Toxicity Screening Test. Twelve male and 12 female Wistar rats per group were exposed to 0, 2500 or 5000 ppm 2-butene for 6 hours/day, 7 days/week. Males were exposed for 39 to 46 days; females were exposed two weeks prior to mating, through mating, and to gestation day 19. Body weights and food consumption were recorded. At study termination, hematology and clinical chemistries were conducted on blood, gross necropsies were conducted, organs weights were recorded and tissues processed for microscopic evaluation. Control and high dose groups, only, were evaluated microscopically. Body weight change was lower for male rats in the first and fourth weeks of exposure in the 2500 ppm group and in the first week in the 5000 ppm group. Female body weights were reduced in the 2500 ppm group at 14 days of exposure and the 5000 ppm group at 7 and 14 days of exposure. Female body weights were comparable during mating and gestation, but were reduced in the 5000 ppm group on lactation day 1. Male rats in both exposure groups had increased total white cell and lymphocyte counts, however there was no dose-response and counts were within the historical control range. A decrease in plasma calcium concentration was observed in high dose males. No developmental (or reproductive) toxicity was observed. No treatment-related increase in pre-implantation loss occurred. Post-implantation loss was slightly increased in the 5000 ppm exposure group, however it was within the historical control range. The total number of live births in the exposed groups was higher than controls. In the control and 2500 ppm groups, one pup died between days 1 and 4 of lactation; the viability index was 97 to 100%. Mean body weights of pups were slightly but not significantly lower in the treated groups, which may be explained by the higher number of pups in the two treatment groups compared to controls. No structural changes were noted in treated pups either during lactation or at necropsy. The systemic toxicity NOAEL was 2500 ppm. The developmental toxicity NOAEL was ≥ 5000 ppm (Waalkens-Grendsen and Arts, 1992). In selecting 2-butene to represent the developmental toxicity of the C1 – C4 HC fraction, the entire C1-C4 HC fraction concentration is

assumed to be equivalent to 100% 2-butene for purposes of calculating C1 – C4 HC developmental toxicity ranges for each petroleum hydrocarbon gas.

Developmental Toxicity (Wistar rats) NOAEL ≥ 5000 ppm (highest dose tested)
Parental Systemic Toxicity (Wistar rats) LOAEL = 5000 ppm
Parental Systemic Toxicity (Wistar rats) NOAEL = 2500 ppm

C5 – C6 Light End Naphtha Hydrocarbons
A developmental toxicity study in rats of Baseline Gasoline Vapor Condensate (BGVC), a 20% light fraction of whole unleaded gasoline was performed according to OPPTS 870.3600, 870.3700 and OECD 414 guidelines. This test material was a representative evaporative emission tested under the USEPA 211(b) Fuels and Fuel Additives Health Effects Testing Program (1994a). BGVC was administered to 25 confirmed-mated female Crl:CD-1®(ICR)BR mice/exposure group at target concentrations of 0, 2000, 10,000, and 20,000 mg/m^3 (mean analytical concentrations 0, 2086, 10625 and 20,903 mg/m^3; 0, 680, 3463, and 6814 ppm) in air. The animals were exposed daily for six hours from Gestation Day 5 through Gestation Day 17. On GD 18, animals were sacrificed and cesarean sections (C-sections) were performed. Gross necropsies were performed, uterine weights with ovaries attached were recorded, uterine contents were examined, and the required uterine implantation data were recorded. All fetuses were weighed, sexed externally, and examined externally for gross malformations. There were no statistically significant differences from control in the treated groups in the incidence of fetal observation. Slight emaciation was the only clinical sign noted during the study and was noted in one of the dams in the highest exposure group (6814 ppm) on Gestation Day 11. Maternal toxicity was evident as statistically significant differences in mean gestation body weight and mean gestation body weight change in the 6,814 ppm target group. Statistically significant reduced fetal body weights, compared with the control fetal weights, were noted in the 3,463 and 6,814 ppm target concentration groups. The reduction of these fetal weights occurred in the absence of statistically significant reductions in maternal body weight and body weight change in the 3,463 mg/m^3 target concentration group. Therefore, the mouse NOAEL for this study was established at the 680 ppm and the mouse LOAEL was 3,463 ppm (API, 2009b). A developmental toxicity study was also conducted in Sprague-Dawley rats using the same test material and protocol. There was no maternal or developmental toxicity in the rats. The rat maternal and developmental toxicity NOAEL was ≥ 6729 ppm, the highest dose tested (API, 2008b).

LOAEL (CD-1 mice) = 3,463 ppm (10,635 mg/m^3)
NOAEL (CD-1 mice) = 680 ppm (2,086 mg/m^3)

Developmental Toxicity Conclusion

Developmental effects were induced by two of the petroleum hydrocarbon gas constituents, benzene and the C5 - C6 hydrocarbon fraction. No developmental toxicity was observed at the highest exposure levels tested for the other petroleum hydrocarbon gas constituents tested for this effect. The asphyxiant gases have not been tested for developmental toxicity. Based on LOAEL and NOAEL values, the order of acute toxicity of these constituents from most to least toxic is[4]:

Benzene (LOAEL = 20 ppm) > butadiene (NOAEL ≥ 1,000 ppm) > C5 – C6 HCs (LOAEL = 3,463 ppm) > C1 – C4 HCs (NOAEL ≥ 5,000 ppm; assumed to be 100% 2-butene) > asphyxiant gases (hydrogen, carbon dioxide, nitrogen)

7.5 Reproductive Toxicity

Benzene
Male and female fertility have been investigated in laboratory animals in studies of different quality and validity via the inhalation route of exposure. There is one inhalation fertility study on female rats available (Kuna et al., 1992), in which female Sprague-Dawley rats were exposed to dose levels of 1, 10, 30, and 300 ppm benzene (6 h/day, 5

[4] ranking is not precise since several values were the highest dose tested

d/week) during premating and mating (10 weeks), gestation and lactation periods up to post-natal day 21. No effects on fertility were observed, however, this study was limited in that the potential for benzene to affect fertility in male rats was not assessed. In addition, systemically toxic concentration levels were not tested. Consequently, it is more appropriate to use a well-conducted 90-day subchronic study to evaluate the potential reproductive hazards of benzene. The reproductive toxicity of benzene was assessed by evaluation of male and female reproductive organs in a 90-day subchronic study. This study investigated the systemic effects of a 13 week benzene (whole chamber, vapor) exposure by inhalation. Male and female CD-1 mice (40 mice/sex/dose) were exposed (0, 1, 10, 30, or 300 ppm benzene; 6h/day, 5 days/week) for 13 weeks. Criteria used to evaluate exposure related effects included behavior, body weights, organ weights, clinical pathology, gross pathology, and histopathology. All animals were observed twice daily, before and after exposure and on nonexposure days, for mortality and moribundity throughout the study. At weekly intervals animals were observed for signs of toxicity, weighed and individual body weights recorded. On study days 7, 14, 28, 56, and 91, blood samples were taken from randomly selected mice (20 mice/sex/group) for full range hematological and clinical chemistry examinations. Blood was collected for clinical pathology analyses from an additional 30 mice one day prior to the start of the study. For interim sacrifice on days 7, 14, 28, 56, and for terminal sacrifice on day 91, 20 mice/sex/group were randomly selected and killed. Complete necropsies were performed on all these animals and on animals found dead or sacrificed in a moribund condition during the study. With respect to reproductive organs, absolute testes weight and testes/terminal body weight ratios were determined for each animal that was necropsied at each interval. In addition, the following tissues from each animal necropsied at each sacrifice interval were taken and fixed: testes or ovaries, prostate or uterus, and mammary gland. Sections from the control and high-level groups at each sacrifice period were subject to histopathological examinations. The testes and ovaries of all animals at all exposure levels at the 91-day terminal sacrifice were examined microscopically. With respect to reproductive organs a statistically significant and exposure-time related decrease in absolute mean testes weights at sacrifices on days 28, 56, and 91, as well as in relative mean testes weights at sacrifices on days 59 and 91 occurred at the 300 ppm level (data not provided). Histomorphologic changes in reproductive organs were also reported at 300 ppm in male mice at the 91 day-interval (seven mice with minimal to moderately severe bilateral atrophy/degeneration of testes, 6 mice with moderate to moderately severe decrease in spermatozoa, 9 mice with minimal to moderate increase in abnormal sperm forms) but not in those sacrificed at the earlier intervals. At the 300 ppm dose level, four female mice showed bilateral ovarian cysts. The severity of gonadal lesions was greater in the males. Similar lesions were reported to be observed in both sexes also at lower dose levels, which the authors considered of doubtful biological significance, and it is assumed that these levels did not represent any significant changes from the controls. Other histopathological changes observed at the high-dose level included the thymus, femoral marrow, spleen, mesenteric lymph nodes, mandibular lymph nodes and the liver, the severity increasing with time. Based on bilaterial cysts in ovaries, atrophy/degeneration of testes, decrease in spermatozoa, and increase in abnormal sperm, the reproductive LOAEL and NOAEL for both sexes was 300 ppm and 30 ppm, respectively (Ward *et al.*, 1985).

LOAEL (male and female CD-1mice) = 300 ppm
NOAEL (male and female CD-1 mice) = 30 ppm

1,3-Butadiene
The reproductive toxicity of 1,3-butadiene was evaluated in an OECD Guideline #421 study in Sprague Dawley rats. Three groups of 12 male and 12 female SpragueDawley rats were exposed to 0, 300, 1,500, and 6,000 ppm 1,3-butadiene via whole-body inhalation exposure 6 h/day for 14 days prior to the breeding period and continuing throughout the gestation and lactation periods. A control group was exposed to clean, filtered air on a comparable regimen. For F0 dams, the daily inhalation exposures were suspended on gestation day 21 through lactation day 4, to avoid any confounding effects of exposure on nesting or nursing behavior. Exposures were resumed for these dams on lactation day 5. The F1 generation pups were exposed to 1,3-butadiene *in utero* and through nursing during lactation until weaning. Beginning on postnatal day 21, one male and one female from each litter were exposed for seven consecutive days to the same concentration of 1,3-butadiene concentration as its dam. Beginning on postnatal day 28, one previously unexposed male and one previously unexposed female per litter were exposed for seven consecutive days to the same 1,3-butadiene concentration as its dam. Assessments of gonadal function, mating behavior, conception, gestation, parturition, lactation of the F0 generation, and the development of F1 offspring from conception through weaning and post-weaning exposure were included in this study. No adverse treatment-related effects were observed for any parameter measured in either the F0 or F1 animals at the exposure level of 300

ppm. At 1,500 and 6,000 ppm , there were effects which consisted of persistent reductions in body weight parameters in F0 and F1 males and females and transient reductions in food consumption (week 0-1) for F0 males and females. Adverse effects noted only at the high dose of 6,000 ppm consisted of clinical observations indicative of chromodacryorrhea, chromorhinorrhea, and salivation in F0 males and females as well as infrequent occurrences of dried red material in the perioral and perinasal regions of four exposed F1 pups (three males and one female). Based on the results of this study, an exposure level of 300 ppm was considered to be the NOAEL in rats for F0 parental systemic toxicity and for systemic toxicity for F1 animals following post-weaning 6-h daily exposures (postnatal day 21-27 or postnatal day 28-34). Parental systemic toxicity LOAEL and NOAEL was 1500 ppm and 300 ppm, respectively. The NOAEL for effects on gonadal function, mating behavior, conception, gestation, parturition, lactation of the F0 generation, and the development of F1 offspring from conception through weaning was considered to be ≥ 6,000 ppm (WIL Research Laboratories, 2003).

Reproductive NOAEL ≥ 6,000 ppm (highest dose tested)
Parental systemic LOAEL = 1500 ppm
Parental systemic NOAEL = 300 ppm

C1 – C4 Hydrocarbons
The reproductive toxicity of isobutane was assessed in an OECD 422 Combined Repeated Dose Toxicity Study with the Reproduction/Developmental Toxicity Screening Test. Neurotoxicity was also evaluated. The test substance was administered as a gas to Sprague Dawley CD rats (12/sex/main study group and 12 females/satellite group) at target concentrations of 900, 3000 and 9000 ppm (note: highest dose is 50% of the lower explosive limit) for 6 hours/day, 7 days/week for 2 weeks prior to mating initiation. Main study male rats were exposed during the mating and post-mating periods until euthanized for a minimum exposure of 28 days. Main study female rats (12/group) were exposed once daily (6 hours/day), 7 days/week for 4 weeks (minimum of 28 days). Satellite female rats were exposed once daily (6 hours/day), 7 days/week for at least two weeks prior to mating initiation. Satellite female rats continued to be treated once daily (6 hours/day) during mating. After mating, satellite female rats were treated once daily (6 hours/day) during gestation days 0-19. Main study females were evaluated for subchronic effects and satellite females for reproductive effects only. The following parameters were evaluated in all animals: viability, clinical observations, body weights, feed consumption, functional observational battery (FOB), motor activity, clinical pathology (termination), organ weights, and macroscopic observations. Microscopic pathology was conducted in the main study control and high-exposure groups only). No parental systemic toxicity was observed. In the 9000 ppm group, 3/12 (25%) of the mated females did not become pregnant. Although not statistically significant, the reduction in the male and female fertility indices (75%) was considered exposure-related since it was below the concurrent control (100%) and the testing facility historical control values (mean 96.4%; range 87.5% - 100%). Mating index for the male rats treated with the test substance was comparable to the air control group. A small but statistically significant ($p < 0.05$) exposure-related increase in post-implantation loss was also observed for the 9000 ppm group of exposed female rats; mean losses of 0.8 ± 0.9 and 1.8 ± 0.8 for control and high exposure groups, respectively. These findings should be interpreted with caution due to the low statistical power associated with this screening level study due to the small number of animals per group (n=12). Consequently the data were interpreted as conservatively as possible; the two reproductive toxicity findings were attributed to isobutane exposure. All other reproductive endpoints were comparable to controls (number of pairs cohabited, number of pairs mated, mating index, gestation index, mean time to mating, mean gestation length, number of females completing delivery with stillborn pups/all stillborn pups, mean pre-implantation loss, mean pups delivered, live birth index, viability index). Pup endpoints (viabilty to day 4, weight and weight gain, sex ratio) were also comparable to air control pups. In conclusion, exposure of male and female rats to target concentrations of 900, 3000 or 9000 ppm of isobutane by whole-body inhalation for 4-6 weeks resulted in no general systemic/neurotoxic effects. A no-observed-adverse effect level (NOAEL) of ≥ 9000 ppm was determined for all general systemic/neurotoxic endpoints in this study. The NOAEL for pup endpoints was 9000 ppm, the highest concentration tested as there were no effects in offspring survival, body weight and development up to post-natal day 4 (HLS, 2008d). Based on decreased male and female fertility and increased post-implantation loss in the 9000 ppm group, the reproductive toxicity NOAEL was determined to be 3000 ppm. In selecting isobutane to represent the reproductive toxicity of the C1 – C4 HC fraction, the entire C1-C4 HC fraction concentration is assumed to be 100% isobutane for purposes of calculating C1 – C4 HC reproductive toxicity ranges for each petroleum hydrocarbon gas. This is a worst case approach as other alkane gases did not product reproductive effects when tested in studies of similar design (see Appendix 4).

Reproductive LOAEL (Sprague Dawley rats) = 9000 ppm
Reproductive NOAEL (Sprague Dawley rats) = 3000 ppm
Developmental NOAEL (Sprague Dawley rats) = 9000 ppm (highest dose tested)
Parental Systemic NOAEL (Sprague Dawley rats) = 9000 ppm (highest dose tested)

C5 – C6 Light End Naphtha Hydrocarbons
Reproductive toxicity was evaluated in a 2-generation inhalation study with Baseline Gasoline Vapor Condensate (BGVC), a 20% light fraction of whole unleaded gasoline according to OPPTS 870.3800. This test material was a representative evaporative emission tested under the USEPA 211(b) Fuels and Fuel Additives Health Effects Testing Program (1994a). BVCG was administered to Sprague Dawley rats (26/sex/group) at target concentrations of 0, 2000, 10000, and 20000 mg/m^3 (actual concentrations 0, 2014, 10,319 and 20,004 mg/m^3) 6hr/day, 7 days/week for 10 weeks before mating and 2 weeks of mating. Exposure of parental females [P0] with confirmed matings was continued until Gestation Day [GD] 19 and suspended until postpartum day 5 to avoid inducing undue stress to the dams during birth and early lactation. P0 dams continued to be exposed to BGVC until sacrifice at weaning. At weaning of the F1 generation on postpartum day 28, one pup/sex/litter was chosen randomly to continue exposure as the F1 parental generation; littermates were never paired together. Exposure of the F1 parental generation to BGVC began at weaning with 10 weeks of pre-mating exposure and continued on the same schedule as the P0 parental generation through mating gestation and lactation. Physical observations, body weights and food consumption were monitored at least weekly during the study. After approximately 16 weeks of exposure, all parental males [P0 and F1] were sacrificed and all parental females [P0 and F1] were sacrificed on postpartum days 28. Females that failed to mate were sacrificed 25 days after the end of the mating period. Fourteen organs were weighed from all rats and tissues from these organs were examined microscopically from 10 rats from the control and 20000 mg/m3 groups. Reproductive organs from all males and bred females in the control and high dose groups were examined. Sperm evaluations included motility, counts of testicular homogenization-resistant sperm and cauda epididymal sperm, and sperm morphology in the cauda epididymis. Ovarian histopathology included evaluation of primordial follicle population, number of growing follicles and corpora lutea. Pups (F1 and F2 generations) were observed as soon as possible after delivery for sex determination, number of live and dead pups and pup abnormalities. Pups dead at delivery were identified as stillborn or liveborn/found dead based on lung floatation evaluation. Thereafter litters were observed twice daily. On LD 4, F1 litters with more than 10 pups were randomly culled to 10 pups with sex distribution equalized if possible. Pups were examined and weighed on LD1 (delivery day), 4 (pre-culled), 7, 14, 21 and 28. At weaning one pup/sex/group was selected for mating to produce the F2 generation. F1 pups [5/sex/group/assessment] not selected for F1 mating were evaluated for standard Tier 2 neuropathology [40 CFR79.66] or for glial fibrillary acidic protein (GFAP) assessments [40 CFR79.67] on postpartum day 28 [Results of the GFAP study are reported in a separate Neurotoxicity robust summary but the GFAP assay is considered beyond the scope of this document]. The remaining pups were sacrificed. Three pups/sex/litter in each group were selected for macroscopic examination and selected organs [brain, spleen, thymus] were weighed from one pup/sex/litter.

Exposure of rats to 2014, 10,319 and 20,004 mg/m^3 of BGVC resulted in decreased body weight gains in the P0 females and F1 males prior to mating in the 20004 mg/m³ exposed group. Increases in kidney weights in parental male animals exposed to the two higher exposure levels of vapor were consistent with alpha 2-microglobulin mediated nephropathy seen in male rats, a finding has been generally accepted not to be relevant to human risk assessment (USEPA, 1991). There was no effect at any of the exposure levels on reproductive performance in the study, including mating, fertility, parturition, lactation, offspring survival and development or maturation, in either the P0 or F1 generations. Pregnancy rates for control, 2014, 10,319 and 20,004 mg/m^3 groups were 96.0%, 96.2%, 92.3% and 100% respectively for P0 animals and 100%, 100%, 91.7% and 100%, respectively for F1 animals. There was no evidence of any neurological effects in F1 pups as a result of the exposures. The NOAEL for systemic toxicity [excluding kidney effects in male rats] is 10319mg/m³. The NOAEL for neurotoxicity in F1 animals is >20,004 mg/m³. The Reproductive NOAEL was ≥ 20,004 mg/m³. The results of the fertility assessment are comparable to those seen in other gasoline reproductive toxicity studies (Mckee *et al*, 2000) and with the refinery streams representative of the 4 chemical classes (API, 2008c).

NOAEL (Sprague Dawley rats) ≥ 6521 ppm; (20,004 mg/m^3; highest dose tested)

Reproductive Toxicity Conclusions

Reproductive effects were induced by only two petroleum hydrocarbon gas constituents, benzene and isobutane (a constituent of the the C1-C4 hydrocarbon fraction). No reproductive toxicity was observed at the highest exposure levels tested for the other petroleum hydrocarbon gas constituents tested for this effect. The asphyxiant gases have not been tested for reproductive toxicity. Based on LOAEL and NOAEL values, the order of reproductive toxicity of these constituents from most to least toxic is[5]:

Benzene (LOAEL = 300 ppm) > butadiene (NOAEL ≥ 6,000 ppm) > C5 – C6 HCs (NOAEL ≥ 6,521 ppm) > C1 – C4 HCs (LOAEL = 9,000 ppm; assumed to be 100% isobutane) > asphyxiant gases (hydrogen, carbon dioxide, nitrogen)

7.6 Petroleum Hydrocarbon Gases Human Health Effects Read Across Method

The mammalian health hazards associated with Petroleum Hydrocarbon Gases were characterized by 8 gas constituents that occur in concentrations ranging from 0 – 99.9% in Petroleum Hydrocarbon Gases. The 8 constituents used to characterize health-related SIDS endpoints for each of the 62 Petroleum hydrocarbon gases in the category are:

- Hydrocarbon Gases
  - Benzene
  - 1,3-Butadiene
  - C1 – C4 Hydrocarbons
  - C5 – C6 Hydrocarbons
- Asphyyxiant Gases
  - Carbon dioxide
  - Hydrogen gas
  - Nitrogen gas

The endpoint toxicity values (acute LC50, reproductive toxicity LOAEL/NOAEL, etc.) for each gas constituent have been adjusted to account for dilution of the constituent in each petroleum hydrocarbon gas. This adjustment represents the calculated concentration of the petroleum hydrocarbon gas required to reach the toxicity value (LC50, LOAEL, etc.) corresponding to the gas constituent in its pure state. For example, if the reproductive toxicity LOAEL for neat (100%) benzene is 300 ppm, the LOAEL for a petroleum hydrocarbon gas containing only 2% (wt./v) benzene would be fifty times more than 100% benzene, or 15,000 ppm; *i.e* it would take fifty times more of the petroleum hydrocarbon gas containing 2% benzene to reach the reproductive toxicity LOAEL for benzene, when the petroleum hydrocarbon gas is diluted with air.

LOAEL values were used to characterize constituent hazards for repeated-dose, developmental, and reproductive toxicities; the NOAEL value was used only if a LOAEL has not been established for any constituent in the petroleum hydrocarbon gas. Similarly, for acute toxicity, measured LC50 values from experiments where mortality was observed and an LC50 value was experimentally derived, were used to characterize acute hazard for each petroleum hydrocarbon gas. Values for constituents where no mortality was observed at the highest exposure level tested (*i.e.* C1 – C4 and C5 – C6 HCs) were used only for streams that do not contain constituents with measured LC50 values.

There are multiple constituents in the majority of the petroleum hydrocarbon gas streams. For hazard characterization, the constituent that has the lowest overall effect level for a particular endpoint was used to characterize the hazard for the entire petroleum hydrocarbon stream for that endpoint. For all constituents except the C1 – C4 HC fraction, there is one toxicity value per endpoint per constituent; *i.e.* constituents were either individual chemicals (*e.g.* benzene) or groups of hydrocarbons (C5 – C6 HC fraction). For the C1 – C4 HC fraction, the most

[5] ranking is not precise since several values were the highest dose tested

toxic individual individual constituent (*e.g.* 2-butene) was selected to characterize the fraction. It is assumed that the C1 – C4 fraction is equivalent to the individual HC selected to represent the C1 – C4 fraction hazard value for each SIDS mammalian toxicity endpoint. The formula used to correct for gas constituent dilution, as well as a detailed example for using the calculation to develop the minimum – maximum concentration value range to characterize the potential hazard for a specific endpoint to a petroleum hydrocarbon gas follows.

Dilution correction calculation formula:

Toxicity value correction for dilution of a constituent in a specific petroleum hydrocarbon gas is calculated by:

$$CV_n = TV_{neat} / TC_n$$

CV_n = corrected endpoint toxicity value for petroleum hydrocarbon gas *n*
TV_{neat} = endpoint toxicity value for the neat (100%) constituent
TC_n = concentration of the constituent in petroleum hydrocarbon gas_n expressed as the decimal value for percent concentration (wt/v).

Dilution correction calculation example:

CASRN 68409-99-4 *Gases (petroleum), catalytic cracked overheads* contains the following components presented as wt/v%:

- C1 – C4 HCs = 65 - 93%
- C5 – C6 light naphtha HCs = 7 - 31%
- Hydrogen = 0 - 3%
- Carbon dioxide = 0 - 1%
- Butadiene = 0.5 – 4%

The following steps are required to derive the Repeated-Dose Toxicity read across range of values for petroleum hydrocarbon gas stream CASRN 68409-99-4:

1. Look up the repeated-dose LOAEL values for each component in Data Matrix Table 9
2. Use the *dilution correction calculation formula* presented above to derive CV*n*, the corrected endpoint toxicity value for petroleum hydrocarbon gas *n*
3. Compare the dilution-corrected LOAEL value ranges, and select the lowest LOAEL values (*i.e.* LOAEL for the most toxic constituent)
4. The read across repeated-dose LOAEL value for CASRN 68409-99-4 is the value selected in step #3

Step 1 – Repeated-dose LOAEL values for neat (100%) components of the petroleum hydrocarbon gas –
C1 – C4 HCs LC50 = 2,500 ppm
C5 – C6 light naphtha HCs LC50 = 6,625 ppm
Hydrogen LOAEL – not applicable; an asphyxiant gas; it is not toxic until it reaches concentrations > 80.5% of the atmosphere
Carbon dioxide LOAEL - not applicable; an asphyxiant gas; it is not toxic until it reaches concentrations > 80.5% of the atmosphere
Butadiene = 8,000 ppm

Step 2 – correct respective LOAEL values for component dilution

C1 – C4 HCs = 65 - 93%
- Low end of range: CV_a = 10,000 ppm/0.09 = **2,688 ppm**
- High end of range: CV_a = 10,000 ppm/0.009 = **3,846 ppm**

C5 – C6 light naphtha HCs = 7 - 31%
- Low end of range: CV_a = 1063 ppm/0.01 = **21,371 ppm**

- High end of range: CV_a = 1063 ppm/0.001 = **94,643 ppm**

Butadiene = 0.5 – 4%

- Low end of range: CV_a = 1590 ppm/0.10 = **200,000 ppm**
- High end of range: CV_a = 1590 ppm/0.001 = **1, 600,000 ppm** (> 100 % of the petroleum hydrocarbon gas)

Step 3 – compare corrected repeated-dose LOAEL values, and selet lowest values

C1-C4 hydrocarbon fraction (2,688 ppm – 3,846 ppm) has the lowest corrected repeated-dose LOAEL range

Step 4 – assign repeated-dose LOAEL read across values for CASRN 68409-99-4

Repeated-Dose LOAEL range for CASRN 68409-99-4= 2,688 ppm – 3,846 ppm

The same four steps can be used to calculate corrected, LC50, developmental, and reproductive toxicity values by substituting the respective LC50 or LOAEL (NOAEL) for the repeated-dose values in the example above. No dilution correction calculations were required for *in vitro* and *in vivo* genetic toxicity endpoints since they were treated as qualitative endpoints and as such, were designated as either *negative* or *positive.* The dilution correction calculations for each of the 99 petroleum hydrocarbon gases used to determine the constituent with the lowest effect level for each endpoint and toxicity value ranges for each petroleum hydrocarbon gas are presented in Appendix 5, which is appended as a separate Excel™ spreadsheet file to this category analysis document.

7.7 Human Health Effects Conclusions

The screening level mammalian health hazards associated with Petroleum Hydrocarbon Gases have been characterized by the constituents (as listed above) of each petroleum hydrocarbon gas. Petroleum hydrocarbon gas constituent hazard data were used to characterize SIDS endpoints for each of the 99 Petroleum Hydrocarbon Gases in the category. To accomplish this, the endpoint value (acute LC_{50}, reproductive toxicity NOAEL/LOAEL, etc.) for a specific gas constituent has been adjusted for dilution of each constituent in the respective petroleum hydrocarbon gas. This adjustment for the dilution of each component in a petroleum hydrocarbon gas represents the calculated concentration of the petroleum hydrocarbon gas required to reach the toxicity value (LC_{50}, NOAEL, etc.) corresponding to the pure substance. For example, if the reproductive toxicity LOAEL for neat (100%) benzene is 300 ppm, the LOAEL for a petroleum hydrocarbon gas containing only 2% (wt./v) benzene would be fifty times more than 100% benzene, or 15,000 ppm; *i.e.* at a petroleum hydrocarbon gas concentration of 15,000 ppm, the benzene concentration would be 300 ppm, equal to its reproductive toxicity LOAEL value. In many cases, there is more than one potentially toxic constituent in a petroleum hydrocarbon gas. In those cases, the constitutent that is most toxic for a particular endpoint in an individual petroleum hydrocarbon stream is used to characterize the endpoint hazard for that stream.

This approach to correct for the concentration of the individual petroleum hydrocarbon gas constitutents to estimate the potential toxicity for mammalian endpoints makes it difficult to draw general conclusions as to which constituents are the most hazardous for human health effects of petroleum hydrocarbon gases as a category. The hazard potential for each mammalian endpoint for each of the 99 petroleum hydrocarbon gases is dependent upon each petroleum hydrocarbon gas constituent endpoint toxicity values (LC50, LOAEL, etc.) and the relative concentration of the constituent present in that gas. It should also be noted that for an individual petroleum hydrocarbon gas, the constituent characterizing toxicity may be different for different mammalian endpoints, again, being dependent upon the concentration of the different constituents in each, distinct petroleum hydrocarbon gas.

8. EXPOSURE

8.1 Overview

Refineries and gas plants create and process a wide variety of gaseous streams, but numerically, few substances in the Hydrocarbon Gases Category leave the facilities. However, large volumes of natural gas and liquefied petroleum gases (LP-gases) are sold to industries and consumers. Occupational exposure to these substances is limited by exposure standards and their inherent flammability hazard. Potential releases into the environment are highly controlled by existing USEPA regulations under the Clean Air Act. The products produced from substances in the Hydrocarbon Gas Category are distributed to consumers through closed systems, usually pipes or tanks and used primarily as fuel. These applications are regulated by various fire codes and the Consumer Product Safety Commission (CPSC).

8.2 Product Specifications

Fungible products within this Category include natural gas and various LP-gases. Products from the refining of crude oil or raw gas are rarely, if ever, sold by TSCA Inventory identifiers. The refining and sale of petroleum products pre-dates development of CAS and TSCA nomenclature. The fungible products that leave a gas plant or refinery are sold based on the product meeting certain performance, physical, or chemical specifications which make them fit for purpose (i.e., HD-5 propane, "on-road" diesel fuel, and USP white mineral oil). Some specifications for the primary fungible products used in the USA are found in Tables 6, 7, and 8. Often, other specifications are set between supplier and customer as needed for commercial purposes. Individual substances (i.e., ethane, propane, butane, etc.) of high purity (>99%) are also commercially available for special purposes.

The composition of LP-gases may vary depending the source and the ratios of propane and butane content. They exist as gases at atmospheric pressure and ambient temperatures, but are readily liquefied under moderate pressure for transportation and utilization. The specifications for the LP-gas products limit the amount of higher molecular weight constituents that can be present. The result is that exposures to benzene, hexane, etc. as a consequence of LP-gas utilization are unlikely.

The following may be accepted as a general guide for the common uses of the four types covered by the Gas Processors Association specifications (GPA, 1997).

1. Commercial Propane is the preferred fuel type for domestic, commercial and industrial fuels. It is also a suitable fuel for low severity internal combustion engines.
2. Commercial Butane is used principally as a feedstock for petrochemicals, synthetic rubber, and as a blending stocks or feedstocks in the manufacture of motor gasoline. Its use as a fuel is generally limited to industrial applications where vaporization problems are not encountered; however, small quantities are used as domestic fuel.
3. Commercial Butane-Propane Mixtures covers a broad range of mixtures, which permits the tailoring of fuels of feedstocks to specific needs.
4. Propane HD-5 is less variable in composition and combustion characteristics than other products covered by these specifications. It is also suitable as a fuel for internal combustion engines operating at moderated to high engine severity.

Table 6. LP Gas Specifications (GPA, 1997)

Item	Commercial Propane	HD-5 Propane	Commercial Butane	Commercial B-P Mixtures	Test Method
Composition	Predominantly propane and/or propylene	Not less than 90 liquid volume percent propane. Not more than 5 liquid	Predominantly butanes and/or butenes	Predominantly mixtures of butanes and/or butenes with propane and/or propylene	ASTM D 2163

		percent propylene			
Vapor pressure at 37.8C, kPa, max	1434	1434	483	1434	ASTM D 1267
Volatile residue: Temp. at T95 Or Butane and heavier; Pentane or heavier	 -37 C 2.5% max -	 -37 C 2.5% max -	 36 - 2.0% max	 36 - 2.0% max	 ASTM D 1837 ASTM D 2163
Residual matter	0.05 ml	0.05 ml	-	-	ASTM D2158
Corrosion, copper strip, max	No. 1	No. 1	No. 1	No. 1	ASTM D 1838
Total sulfur, ppmw	185	123	140	140	ASTM D 2784
Moisture or free water content	Pass	Pass	None	None	ASTM D 2713

The Gas Processors Association (GPA, 1997) states that their specifications generally define physical properties and characteristics of LP-Gas which make them suitable for private, commercial, or industrial applications. However, their specifications do not purport to specifically define all possible requirements to meet all possible applications. Therefore the user is cautioned to exercise judgment in formulating final specifications for specific applications.

EPA has established the following specifications for natural gas and LP-gas when used as motor fuels.

Table 7. Test fuel specifications for natural gas[1] (EPA, 40 CFR 1065.215)

Item	Procedure	Value (mole percent)
1. Methane	ASTM D 1945-96	87.0 minimum.
2. Ethane	ASTM D 1945-96	5.5 maximum.
3. Propane	ASTM D 1945-96	1.2 maximum.
4. Butane	ASTM D 1945-96	0.35 maximum.
5. Pentane	ASTM D 1945-96	0.13 maximum.
6. C6 and higher	ASTM D 1945-96	0.1 maximum.
7. Oxygen	ASTM D 1945-96	1.0 maximum.
8. Inert gases	ASTM D 1945-96	5.1 maximum.

[1] At ambient conditions, the fuel must have a distinctive odor detectable down to a concentration in air of not more than one-fifth of the lower flammability limit.

Table 8. Test fuel specifications for liquefied petroleum gas[1] (EPA, 40 CFR 1065.220)

Item	Procedure	Value
1. Propane	ASTM D 2163-91	85.0 vol. percent minimum.
2. Vapor pressure	ASTM D 1267-02	14 bar maximum.
3. Volatile residue	ASTM D 1837-02	-38° C maximum.
4. Butanes	ASTM D 2163-91	5.0 vol. percent maximum.
5. Butenes	ASTM D 2163-91	2.0 vol. percent maximum.
6. Pentenes and heavier	ASTM D 2163-91	0.5 vol. percent maximum.

7. Propene	ASTM D 2163-91	10.0 vol. percent maximum.
8. Residual matter	ASTM D 2158-02	0.05 ml maximum pass.
9. Corrosion, copper strip	ASTM D 1838-91	No. 1 maximum.
10. Sulfur	ASTM D 2784-98	80 ppm maximum.
11. Moisture content	ASTM D 2713-91	pass.

[1] At ambient conditions, the fuel must have a distinctive odor detectable down to a concentration in air of not over one-fifth of the lower flammability limit.

For certain applications including, but not limited to, use of LP-gas for residential and commercial fuels, users of LP-gas should be aware of additional requirements of other standards, principally, "Storage and Handling of Liquefied Petroleum Gases" (NFPA 58) and other regulations (DOT, 49 CFR 173.315(b)(1)). NFPA 58 has been adopted widely by local, state, and other regulator bodies in the form of laws, ordinances, or regulations governing the safe storage, transportation, and use of LP-gas as fuels.

Among other requirements, NFPA 58 (sec.1-4.1.1) stipulates that LP-gases "be odorized by the addition of a warning agent of such character that they are detectable, by a distinct odor, down to a concentration in air of not over one-fifth the lower limit of flammability". NFPA notes that "ethyl mercaptan in the ratio of 1.0 lb per 10,000 gallons of liquid LP-Gas has been recognized as an effective odorant.

8.3 Exposure Scenarios

8.3.1 Environmental Exposure

Releases into the environment can occur as low level fugitive emissions from flanges and valves, a temporary release from a malfunctioning flare or other control systems, or as a catastrophic release from a ruptured pipe or tank. Emissions to air are the only likely means by which gases would be released to the environment. Current USEPA regulations under the Clean Air Act limit the amount of fugitive emissions, specify maximum achievable control technologies (MACT), and require planning and warnings for potential catastrophic releases. Releases from consumer use of gaseous fuels and products (aerosol propellants) are regulated by the CPSC.

8.3.2 Occupational Exposure

If a Petroleum Hydrocarbon Gas Category substance is released into the air, the individual constituents separate and partition in accordance with their own individual physical-chemical properties. There are enforceable (OSHA Permissible Exposure Limits; PELs) and recommended (ACGIH) occupational exposure standards for a majority of the constituents typically found in Petroleum Hydrocarbon Gas Category substances. Below is a Table of current occupational exposure standards established by OSHA (OSHA, 2009 online; HSDB 2009 online), and the American Conference of Governmental Industrial Hygienists (ACGIH, 2008). These standards, particularly the enforceable OSHA standards, are one means by which human exposures to individual gas constituents are controlled; control of exposure to hazardous constituents of petroleum hydrocarbon gases additionally places a control on exposures to entire petroleum hydrocarbon gas streams that contain the hazardous constituent(s).

Table 9. OSHA and ACGIH Occupational Exposure Standards for Hydrocarbon Gas Components (8-hour Time Weighted Averages)

Component Class	Alkanes	Olefins	Alkadienes	> C4	Inorganics
Component OSHA and/or ACGIH Occupational Exposure Standard	**Methane** **OSHA** Asphyxiant **ACGIH** Asphyxiant			**LPG** **ACGIH** 1000 ppm	**Hydrogen** **ACGIH** Asphyxiant
	Ethane	**Ethylene**		**Gasoline Vapor**	**Nitrogen**

Component Class	Alkanes	Olefins	Alkadienes	> C4	Inorganics
	ACGIH 1000 ppm	**ACGIH** 200 ppm		**ACGIH** 300 ppm	**ACGIH** Asphyxiant
	Propane **OSHA** 1000 ppm **ACGIH** 1000 ppm	**Propylene** **ACGIH** 500 ppm		**Benzene** **OSHA** 1 ppm **ACGIH** 1 ppm	**Carbon dioxide** **OSHA** 5000ppm **ACGIH** 5000 ppm
	Butane **ACGIH** 1000 ppm	**1-Butene** **ACGIH** 250 ppm		**Hexane** **OSHA** 500 ppm **ACGIH** 50 ppm	
	Propane, 2-methyl **ACGIH** 1000 ppm	**2-Butene** **ACGIH** 250 ppm	**1,3-Butadiene** **OSHA** 1ppm **ACGIH** 2 ppm		
		Propene, 2-methyl ACGIH: 250 ppm			

Flammability is a common hazard of substances in the Petroleum Hydrocarbon Gases Category. Below is a Table which presents the lower and upper explosive limits for key constituents of the substances in this Category. The range of the lower explosive limit is 11,000 to 50,000 ppm.

Table 10. Explosive Limits for Key Category Constituents

Fuel Gas	"Lower Explosive or Flammable Limit" (LEL/LFL) (%)	"Upper Explosive or Flammable Limit" (UEL/UFL) (%)
Benzene	1.3	7.1
Butane	1.8	8.4
Butylene	1.98	9.65
Ethane	3	12.4
Ethylene	2.7	36
Hydrogen	4	75
Isobutane	1.8	9.6
Isobutene	1.8	9

Isopentane	1.32	9.16
Gasoline	1.4	7.6
Methane	5	15
n-Hexane	1.1	7.5
Propane	2.1	10.1
Propylene	2.0	11.1

8.3.3 U.S. Chemical Safety and Hazard Investigation Board

The CSB is an independent federal agency charged with investigating industrial chemical accidents. The CSB conducts root cause investigations of chemical accidents at fixed industrial facilities. Root causes are usually deficiencies in safety management systems, but can be any factor that would have prevented the accident if that factor had not occurred. Other accidental causes often involve equipment failures, human errors, unforeseen chemical reactions or other hazards. The agency does not issue fines or citations, but does make recommendations to plants, regulatory agencies such as the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (USEPA), industry organizations, and labor groups. Recent actions by the CSB that impact the Petroleum Hydrocarbon Gas Category substances are listed below.

June 2006 Dangers of Propylene Cylinders in High Temperatures
January 2006 Explosion at ASCO: Dangers of Flammable Gas Accumulation
June 2003 Hazards of Nitrogen Asphyxiation

8.3.4 Industry Standards and Recommended Practices

The long history of petroleum refining has resulted in the development of recommended practices (RP) and standards (STD) to improve safety within the facilities. API has been a leader in developing these standards for both Upstream and Downstream operations. Listed below are groups of STDs and RPs that help ensure safe operation of the plant and reduce exposures to workers and the surrounding community.

Personnel Safety

API PERSONNEL SAFETY SET

PERSONNEL SAFETY INCLUDES THE FOLLOWING API STANDARDS: STD 2217A, RP 2016, STD 2220RP 2221, RP 54, RP 74, STD 2015

Process Safety

API PROCESS SAFETY SET

PROCESS SAFETY INCLUDES THE FOLLOWING API STANDARDS: PUBL 770, PUBL 9100, RP 751 RP 752

Safety & Fire

API SAFETY & FIRE SET

SAFETY AND FIRE - INCLUDES THE FOLLOWING API STANDARDS: 54, 74, 751, 752, 770, 2001, 2003, 2009, 2015, 2016, 2021, 2021A, 2023, 2026, 2027, 2028, 2030, 2201, 2207, 2210, 2214, 2216, 2217A 2218, 2219, 2220, 2221, 2350, 2510A, 9100

8.4 Consumer Exposure

The products produced from substances in the Hydrocarbon Gas Category are primarily used by consumers as fuel (e.g., LP and natural gas for home heating and cooking, butane in lighters, etc.) but also can be found as propellants in aerosol cans. The CPSC regulates the appliances that burn hydrocarbon gases and the hazard labeling of

flammable aerosol products. While primarily intended to reduce the hazard of fire, the regulations also limit human and environmental exposures. Various fire codes (NFPA 58) require the use of an odorant in consumer products to warn of gas leaks. Ethyl mercaptan is the odorant typically used for natural gas and LP-gases. People are constantly exposed to small quantities of carbon dioxide, ethylene, and methane as they are all produced endogenously.

8.5 Exposure to Children

Because of the way natural gas or LP-gases are distributed to the public (pipes, tanks) little direct exposure of children is anticipated. Older children capable of using spay paints or fuel appliances (i.e., camping) can be exposed to propane-butane mixtures. But because of the fire hazard these substances present, the low toxicity of hydrocarbon gases is of secondary concern.

9. Data Matrixes

Three data matrixes are presented below for this category. The first data matrix (Table 11) presents endpoint values for constituents of the petroleum hydrocarbon gases. Table 12 is the data matrix for Petroleum Hydrocarbon Gas Category members' Physical-Chemical, Environmental Fate, and Ecotoxicology SIDS endpoints; this information is presented as technical discussions. Table 13 is the data matrix for Petroleum Hydrocarbon Gas Category members' Human Health Effects SIDS endpoints.

Table 11. Petroleum Hydrocarbon Gas Components Data Matrix

	Component CAS #						
SIDS Endpoint	Hydrocarbons C1 – C4	Hydrocarbons C5 – C6 (light naphthas)	Benzene 71-43-2	1,3-Butadiene 106-99-2	Hydrogen 1333-74-0	Nitrogen 7727-37-9	Carbon dioxide 124-38-9
Physical-Chemical Properties							
Melting Point °C	-190 – 109	-169 – 6.5	5.5	-109	-259	-210	-56.5
Boiling Point °C	-164 – -0.5	20 – 81	80.1	-4.5	-252.8	-196	-78.5
Vapor Pressure hPa @ 25°C	2,426 hPa – 621,282 hPa	126 – 1204	126	2,813	1,653,198	1013 @ -196°C	64,395
Partition Coefficient Log Kow	1.09 – 2.89	2.13 – 3.9	2.13	1.99	-1.14	0.67	0.83
Water Solubility mg/L	22 – 735	9.5 – 1790	1790	735	1.62	18,100	1,480
Environmental Fate							
Photodegradation T1/2, h or d	3.2 – 960 d	0.2 – 5.5	5.5 d	0.16 d	No	No	No
Stability in Water	stable	stable	stable	stable	stable	stable	stable
Transport and Distribution EQC Level 1	air = 100% water = <0.1% soil = <0.1% other = <0.1%	air = 99.8% water = <0.9% soil = <0.1% other = <0.1%	air = 99% water =0.88% soil = <0.1% other = <0.1%	air = 100% water = <0.1% soil = <0.1% other = <0.1%	air = 100% water = <0.1% soil = <0.1% other = <0.1%	air = 100% water = <0.1% soil = <0.1% other = <0.1%	air = 100% water = <0.1% soil = <0.1% other = <0.1%
Biodegradation	inherently	inherently	inherently	inherently	N/A	N/A	N/A
Environmental Effects							
Acute Toxicity to Fish 96-h LC_{50}, mg/L	6.3 – 137	1.0 – 18	5.3 – 35.7	38	(1)	(1)	(1)
Acute Toxicity to Aquatic Invertebrates 48-h EC_{50}, mg/L	7.2 – 138	1.3 – 20	59.6 - 682	40	(1)	(1)	(1)
Toxicity to Algae 72- or 96-h EC_{50}, mg/L	4.7 – 82	0.9 – 13	29	25	(1)	(1)	(1)

Table 11. Petroleum Hydrocarbon Gas Components Data Matrix

	Component CAS #						
SIDS Endpoint	Hydrocarbons C1 – C4	Hydrocarbons C5 – C6 (light naphthas)	Benzene 71-43-2	1,3-Butadiene 106-99-2	Hydrogen 1333-74-0	Nitrogen 7727-37-9	Carbon dioxide 124-38-9
Human Health Effects[2, 3]							
Acute Inhalation (ppm)	LC_{50} > 10,000(4 hours; highest dose tested)	LC_{50} > 1063 (4 hours; highest dose tested)	LC_{50} = 13,700 (4 hours)	LC_{50} = 129,000 (4 hours)	Asphyxiant[4]	asphyxiant	asphyxiant
Repeated-Dose (ppm)	LOAEL = 5000 NOAEL = 2500	LOAEL = 6625 NOAEL = 3310	LOAEL ≤ 10 (lowest dose tested)	LOAEL = 8000 NOAEL = 1000	n/a	n/a	n/a
Genotoxicity, *in vitro*							
Bacterial systems	negative	negative	positive	positive	n/a	n/a	n/a
Non-bacterial systems	negative	negative	positive	positive	n/a	n/a	n/a
Genotoxicity, *in vivo*	negative	negative	positive	positive (mice)	n/a	n/a	n/a
Reproductive Toxicity (ppm)	LOAEL = 9000 NOAEL = 3000	NOAEL ≥ 6521 (highest dose tested)	LOAEL = 300 NOAEL = 30 (mice)	NOAEL ≥ 6000(highest dose tested)	n/a	n/a	n/a
Developmental Toxicity (ppm)	NOAEL ≥ 9000 (highest dose tested)	LOAEL = 3463 NOAEL = 680 (mice)	LOAEL = 20 NOAEL = 10 (mice)	NOAEL ≥ 1000(highest dose tested)	n/a	n/a	n/a

colored cell = read across data, not measured value

(1) These gases are not known to elicit toxicity to aquatic organisms. However, they may act as asphyxiants if they are released in a manner to aquatic systems whereby they displace dissolved oxygen.

(2) *in vivo* human health effects studies conducted in rats, unless otherwise noted

(3) See human health effects data matrix for each petroleum hydrocarbon gas in Table 11 below and attached Excel spreadsheet

(4) simple asphyxiants cause suffocation by reducing pO_2 to lethal levels without toxic effects on other organ systems; SIDS endpoints are not Provided

Table 12. Petroleum Hydrocarbon Gases Physical-Chemical, Environmental Fate, and Ecotoxicology Data Matrix			
CASRN	**Physical-Chemical Endpoints of Melting Point, Boiling Point, Vapor Pressure, Partition Coefficient, and Water Solubility**	**Environmental Fate Endpoints of Photodegradation, Stability in Water, Environmental Distribution, and Biodegradation**	**Ecotoxicity Endpoints of Acute Toxicity to Fish, Invertebrates, and Algae**
All 62 Petroleum Hydrocarbon Gas Streams CASRNs: 74-82-8 thru 71808-30-5 (see Table 13 or Appendix 1 for a complete list of CASRNs)	All Hydrocarbon Gases Category members are mixtures of primarily hydrocarbons having one to six carbon atoms (alkanes and alkenes) and occasional inorganic gases (H_2, N_2, and CO_2). Proportions of these constituents in the hydrocarbon gas streams vary and may be a large or small fraction of the streams. Physical-chemical data for individual substances identified in hydrocarbon gases are provided in Section 4 of this document. Because of these streams' variable and complex make-up, no single value for these endpoints would be expected to represent the stream as a whole, but the range of values provide a general assessment of the physical-chemical nature of these hydrocarbon gas streams.	When a hydrocarbon gas stream is released into the environment, the individual constituents separate and partition to the different environmental compartments in accordance with their own individual physical-chemical properties. The ultimate fate of individual components in petroleum hydrocarbon gases is influenced by both abiotic and biotic processes. The environmental fate properties of the individual substances identified in hydrocarbon gases are provided in Section 5 of this document. Because these streams' variable and complex make-up, the fate characteristics of the stream would be a composite of the characteristics of the individual components. Because these exist as gases, individual components would be expected to move to the atmosphere and undergo various photochemical and transport mechanisms consistent with their specific processes.	Acute LC/EC50 values for constituents in hydrocarbon gases ranged roughly from 1 to 100 mg/L. Although the LC/EC50 data for the individual gases indicate the potential toxicity to aquatic organisms, aqueous concentrations from atmospheric releases of these gases would not likely attain acute lethal levels. To evaluate the potential for adverse effects to aquatic organisms from an environmental release of hydrocarbon gases, a conceptual exposure model was developed, and a Level 3 fugacity model was applied using the physical-chemical profiles of the individual components. Results from assessing the conceptual exposure model described in Section 6 showed that none of the constituents would partition to water in sufficient amounts to reach levels known to be acutely toxic to aquatic organisms.

Table 13. Petroleum Hydrocarbon Gases Health Effects Data Matrix

CASRN	Endpoint Ranges (ppm)										
	Acute LC_{50}		Repeated-Dose[1]		In vitro Genotoxicity		*In vivo* Genotoxicity	Developmental Toxicity[1]		Reproductive Toxicity[1]	
	Minimum	Maximum[2]	Minimum	Maximum	Bacterial Mutagenicity	Non-bacterial		Minimum	Maximum	Minimum	Maximum
74-82-8	10,101	12,658	2,525	3,165	Negative	Negative	Negative	5,051	6,329	9,091	11,392
	no lethality[3]		C1 – C4 HCs[4]		No genotoxic constituents			NOAEL†		C1 – C4 HCs[5]	
74-84-0	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
74-98-6	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
75-28-5	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
78-78-4	1,063	1,063	6,625	6,625	Negative	Negative	Negative	3,463	3,463	6,521	6,521

[1] Repeated-dose, developmental, and reproductive toxicity numerical ranges represent LOAEL values unless other wise noted with the symbol †

† Numerical ranges represent NOAEL values; endpoint ranges for these petroleum hydrocarbon gases are based on the highest concentration tested for the constituent with the lowest NOAEL; no developmental and/or reproductive toxicity was observed for any constituents of these gases

[2] Minimum and Maximum Toxicity Values represent the concentration ranges of the constituent with the highest degree of toxicity per SIDS endpoint in the specific petroleum hydrocarbon gas; see Appendix 5 (separate EXCEL file) for calculations

[3] Acute toxicity numerical ranges represent measured LC_{50} values from experiments where mortality was observed unless the most toxic constituent is listed as "no lethality"; "no lethality" indicates that no mortality was observed at the highest concentration of any of the individual petroleum hydrocarbon gas constituents tested; consequently this is not a true LC_{50} value range, but rather the range for the highest concentrations tested in a standard LC_{50} assay; the petroleum hydrocarbon gas constituent/constituent fraction with the lowest 'no lethality' value was selected to characterize the acute toxicity for these CASRN (see Section 7.6 for further explanation)

[4] Petroleum Hydrocarbon Gas constituent/constituent fraction responsible for respective endpoint toxicity range for each petroleum hydrocarbon gas CASRN; endpoint ranges are based on dilution calculations; note that the constituent characterizing toxicity may vary by endpoint for the same CASRN; see Appendix 5 (separate EXCEL file)

[5] When C1 – C4 HCs was the constituent characterizing reproductive toxicity, it was assumed that 100% of the C1 – C4 HC fraction was isobutane. This is a worst case approach as other alkane gases did not produce reproductive effects when tested in studies of similar design.

Table 13. Petroleum Hydrocarbon Gases Health Effects Data Matrix

CASRN	Endpoint Ranges (ppm)										
	Acute LC_{50}		Repeated-Dose[1]		In vitro Genotoxicity		*In vivo* Genotoxicity	Developmental Toxicity[1]		Reproductive Toxicity[1]	
	Minimum	Maximum[2]	Minimum	Maximum	Bacterial Mutagenicity	Non-bacterial		Minimum	Maximum	Minimum	Maximum
	no lethality		C5 – C6 HCs		No genotoxic constituents			C5 – C6 HCs		NOAEL†	
106-97-8	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
109-66-0	1,063	1,063	6,625	6,625	Negative	Negative	Negative	3,463	3,463	6,521	6,521
	no lethality		C5 – C6 HCs		No genotoxic constituents			C5 – C6 HCs		NOAEL†	
115-07-1	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
287-92-3	1,063	1,063	6,625	6,625	Negative	Negative	Negative	3,463	3,463	6,521	6,521
	no lethality		C5 – C6 HCs		No genotoxic constituents			C5 – C6 HCs		NOAEL†	
513-35-9	1,063	1,063	6,625	6,625	Negative	Negative	Negative	3,463	3,463	6,521	6,521
	no lethality		C5 – C6 HCs		No genotoxic constituents			C5 – C6 HCs		NOAEL†	
8006-14-2	10,537	11,173	2,634	2,793	Negative	Negative	Negative	5,269	5,587	9,484	10,056
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68131-75-9	> 100%[1]	> 100%	2,500	2,503	Positive	Positive	Positive	5,000	5,005	9,000	9,009
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.1% 1,3-butadiene			NOAEL†		C1 – C4 HCs	
68307-98-2	> 100%	> 100%	2,503	2,591	Positive	Positive	Positive	346,300	> 100%	9,009	9,326
	1,3-Butadiene		C1 – C4 HCs		Contains up to 2% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68307-99-3	> 100%	> 100%	2,515	2,717	Positive	Positive	Positive	346,300	> 100%	9,054	9,783
	1,3-Butadiene		C1 – C4 HCs		Contains up to 2% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68308-02-1	11,976	15,504	2,994	3,876	Negative	Negative	Negative	62,964	230,867	10,778	13,953
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	

[1] Calculated dilution concentration was greater than 1,000,000 ppm; it would require more than 100% of the gas to cause the respective endpoint effect; note, asphyxiation would occur first at concentrations that reduce oxygen concentrations to approximately < 18% (<180,000 ppm)

Table 13. Petroleum Hydrocarbon Gases Health Effects Data Matrix

CASRN	Endpoint Ranges (ppm)										
	Acute LC_{50}		Repeated-Dose[1]		In vitro Genotoxicity		*In vivo* Genotoxicity	Developmental Toxicity[1]		Reproductive Toxicity[1]	
	Minimum	Maximum[2]	Minimum	Maximum	Bacterial Mutagenicity	Non-bacterial		Minimum	Maximum	Minimum	Maximum
68308-03-2	10,173	11,628	2,543	2,907	Negative	Negative	Negative	32,981	203,706	9,156	10,465
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68308-04-3	10,183	11,299	2,546	2,825	Negative	Negative	Negative	43,288	203,706	9,165	10,169
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68308-05-4	>100	>100%	2,503	2,577	Positive	Positive	Positive	346,300	>100%	9,009	9,278
	1,3-Butadiene		C1 – C4 HCs		Contains up to 2% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68308-06-5	5,906	53,150	2,551	3,049	Negative	Negative	Negative	19,239	173,150	9,184	10,976
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68308-08-7	10,000	10,101	2,500	2,525	Negative	Negative	Negative	346,300	>100%	9,000	9,091
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68309-09-8	5,906	53,150	2,551	3,049	Negative	Negative	Negative	19,239	173,150	9,184	10,976
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68308-10-1	10,000	10,204	2,500	2,551	Negative	Negative	Negative	173,150	>100%	9,000	9,184
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68308-11-2	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68308-12-3	> 100 %	> 100 %	1,000	>100%	Positive	Positive	Positive	2,000	>100%	10,601	34,615
	Benzene		Benzene		Contains up to 1% Benzene			Benzene		C1 – C4 HCs	
68409-99-4	> 100 %	> 100 %	2,688	3,846	Positive	Positive	Positive	11,171	49,471	9,677	13,846
	1,3-butadiene		C1 – C4 HCs		Contains up to 4% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68410-63-9	10,537	11,173	2,634	2,793	Negative	Negative	Negative	5,269	5,587	9,484	10,056
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68475-57-0	10,000	10,204	2,500	2,551	Negative	Negative	Negative	5,000	5,102	9,000	9,184
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	

Table 13. Petroleum Hydrocarbon Gases Health Effects Data Matrix

CASRN	Endpoint Ranges (ppm)										
	Acute LC_{50}		Repeated-Dose[1]		In vitro Genotoxicity		*In vivo* Genotoxicity	Developmental Toxicity[1]		Reproductive Toxicity[1]	
	Minimum	Maximum[2]	Minimum	Maximum	Bacterial Mutagenicity	Non-bacterial		Minimum	Maximum	Minimum	Maximum
68475-58-1	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68475-59-2	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68475-60-5	1,635	3,037	3,846	7,143	Negative	Negative	Negative	5,328	9,894	13,846	25,714
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68476-40-4	10,000	10,101	2500	2,525	Negative	Negative	Negative	346,300	>100%	9,000	9,091
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68476-42-6	1,587	3,221	3,731	7,576	Negative	Negative	Negative	5,169	10,494	13,433	27,273
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68476-44-8	>100%	>100%	1,000	>100%	Positive	Positive	Positive	2,000	>100%	17,647	55,556
	Benzene		Benzene		Contains up to 1% benzene			Benzene		C1 – C4 HCs	
68476-49-3	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68476-54-0	>100%	>100%	2,959	4,098	Positive	Positive	Positive	8,879	22,342	10,651	14,754
	1,3-butadiene		C1 – C4 HCs		Contains up to 0.5% 1-3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68476-85-7	>100%	>100%	1,000	>100%	Positive	Positive	Positive	2,000	>100%	14,754	52,326
	Benzene		Benzene		Contains up to 1% benzene and up to 0.1% 1,3-butadiene			Benzene		C1 – C4 HCs	
68476-86-8	>100%	>100%	1,000	>100%	Positive	Positive	Positive	2,000	>100%	14,754	52,326
	Benzene		Benzene		Contains up to 1% benzene and up to 0.1% 1,3-butadiene			Benzene		C1 – C4 HCs	
68477-25-8	>100%	>100%	1,000	>100%	Positive	Positive	Positive	2,000	>100%	11,553	27,273
	Benzene		Benzene		Contains up to 1% benzene			Benzene		C1 – C4 HCs	
68477-33-8	>100%	>100%	2,000	>100%	Positive	Positive	Positive	4,000	>100%	9,375	11,765
	Benzene		Benzene		Contains up to 0.5% benzene and up to 1% 1,3-butadiene			Benzene		C1 – C4 HCs	

Table 13. Petroleum Hydrocarbon Gases Health Effects Data Matrix

CASRN	Endpoint Ranges (ppm)										
	Acute LC_{50}		Repeated-Dose[1]		In vitro Genotoxicity		*In vivo* Genotoxicity	Developmental Toxicity[1]		Reproductive Toxicity[1]	
	Minimum	Maximum[2]	Minimum	Maximum	Bacterial Mutagenicity	Non-bacterial		Minimum	Maximum	Minimum	Maximum
68477-42-9	>100%	>100%	2,577	3,030	Positive	Positive	Positive	20,988	115,433	9,278	10,909
	Benzene		C1 – C4 HCs		Contains up to 0.1% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68477-69-0	10,000	10,204	2,500	2,551	Negative	Negative	Negative	173,150	>100%	9,000	9,184
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68477-70-3	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68477-71-4	> 100%	> 100%	2,688	3,676	Positive	Positive	Positive	10,822	49,471	9,677	13,235
	1,3-Butadiene		C1 – C4 HCs		Contains up to 4% 1-3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68477-72-5	> 100%	> 100%	2,959	4,167	Positive	Positive	Positive	8,658	22,342	10,651	15,000
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.5% 1-3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68477-73-6	> 100%	> 100%	2,500	2,525	Positive	Positive	Positive	346,300	>100%	9,000	9,091
	1,3-Butadiene		C1 – C4 HCs		Contains up to 2% 1-3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68477-74-7	> 100%	> 100%	2,000	>100%	Positive	Positive	Positive	4,000	>100%	9,978	22,785
	Benzene		Benzene		Contains up to 0.5% benzene			Benzene		C1 – C4 HCs	
68477-75-8	> 100%	> 100%	2,723	5,020	Positive	Positive	Positive	7,368	42,232	9,804	18,072
	Benzene		C1 – C4 HCs		Contains up to 0.2% benzene			C5 – C6 HCs		C1 – C4 HCs	
68477-76-9	3,937	22,617	2,623	3,425	Negative	Negative	Negative	12,826	73,681	9,444	12,329
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68477-79-2	> 100%	> 100%	2,572	2,864	Positive	Positive	Positive	10,000	>100%	9,259	10,309
	Benzene		C1 – C4 HCs		Contains up to 0.2% benzene			Benzene		C1 – C4 HCs	
68477-83-8	> 100%	> 100%	2,828	4,274	Positive	Positive	Positive	8,767	29,853	10,181	15,385
	1,3-Butadiene		C1 – C4 HCs		Contains up to 2% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68477-85-0	> 100%	> 100%	2,538	3,378	Positive	Positive	Positive	13,580	230,867	9,137	12,162
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.5% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68477-86-1	10,000	10,753	2,500	2,688	Negative	Negative	Negative	5,000	5,376	9,000	9,677

Table 13. Petroleum Hydrocarbon Gases Health Effects Data Matrix

CASRN	Endpoint Ranges (ppm)										
	Acute LC_{50}		Repeated-Dose[1]		In vitro Genotoxicity		*In vivo* Genotoxicity	Developmental Toxicity[1]		Reproductive Toxicity[1]	
	Minimum	Maximum[2]	Minimum	Maximum	Bacterial Mutagenicity	Non-bacterial		Minimum	Maximum	Minimum	Maximum
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68477-87-2	> 100%	> 100%	2,500	2,660	Positive	Positive	Positive	69,260	>100%	9,000	9,574
	1,3-Butadiene		C1 – C4 HCs		Contains up to 1% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68477-88-3	10,000	10,526	2,500	2,632	Negative	Negative	Negative	5,000	5,263	9,000	9,474
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68477-90-7	10,000	10,753	2,500	2,688	Negative	Negative	Negative	5,000	5,376	9,000	9,677
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68477-91-8	> 100%	> 100%	2,525	2,907	Positive	Positive	Positive	69,260	346,300	9,091	10,465
	1,3-Butadiene		C1 – C4 HCs		Contains up to 2% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68477-94-1	> 100%	> 100%	2,500	2,646	Positive	Positive	Positive	5,000	5,291	9,000	9,524
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.5% 1,3-butadiene			NOAEL†		C1 – C4 HCs	
68478-19-3	10,050	10,526	2,513	2,632	Negative	Negative	Negative	69,260	692,600	9,045	9,474
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68478-24-0	> 100%	> 100%	2,680	3, 682	Positive	Positive	Positive	12,368	51,687	9,646	13,255
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.1% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68478-26-2	> 100%	> 100%	2,513	2,720	Positive	Positive	Positive	69,260	692,600	9,045	9,793
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.1% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68478-32-0	> 100%	> 100%	2,000	> 100%	Positive	Positive	Positive	4,000	> 100%	9,307	13,333
	Benzene		Benzene		Contains up to 0.5% benzene and 1% 1,3-butadiene			Benzene		C1 – C4 HCs	
68478-33-1	10,695	13,245	2,674	3,311	Negative	Negative	Negative	76,956	230,867	9,626	11,921
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68478-34-2	> 100%	> 100%	2,577	3,425	Positive	Positive	Positive	18,226	138,520	9,278	12,329
	1,3-Butadiene		C1 – C4 HCs		Contains up to 4% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68512-91-4	> 100%	> 100%	2,538	3,378	Positive	Positive	Positive	13,580	230,867	9,137	12,162
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.5% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	

Table 13. Petroleum Hydrocarbon Gases Health Effects Data Matrix

CASRN	Endpoint Ranges (ppm)										
	Acute LC_{50}		Repeated-Dose[1]		In vitro Genotoxicity		*In vivo* Genotoxicity	Developmental Toxicity[1]		Reproductive Toxicity[1]	
	Minimum	Maximum[2]	Minimum	Maximum	Bacterial Mutagenicity	Non-bacterial		Minimum	Maximum	Minimum	Maximum
68513-12-2	11,123	14,925	2,781	3,731	Negative	Negative	Negative	115,433	> 100%	10,011	13,433
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68513-15-5	> 100%	> 100%	2,000	> 100%	Positive	Positive	Positive	4,000	> 100%	10,922	24,658
	Benzene		Benzene		Contains up to 0.5% benzene			Benzene		C1 – C4 HCs	
68513-17-7	1,611	6,040	3,034	7,353	Negative	Negative	Negative	5,247	19,676	10922	26,471
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68513-65-5	> 100%	> 100%	2,500	2,564	Positive	Positive	Positive	173,150	> 100%	9,000	9,231
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.5% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68513-66-6	> 100%	> 100%	2,809	3,650	Positive	Positive	Positive	11,171	31,482	10,112	13,139
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.5% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68514-31-8	> 100%	> 100%	2,505	2,717	Positive	Positive	Positive	5,010	5,435	9,018	9,783
	1,3-Butadiene		C1 – C4 HCs		Contains up to 3% 1,3-butadiene			NOAEL†		C1 – C4 HCs	
68514-36-3	> 100%	> 100%	2,503	2,577	Positive	Positive	Positive	5,005	5,155	9,009	9,278
	1,3-Butadiene		C1 – C4 HCs		Contains up to 3% 1,3-butadiene			NOAEL†		C1 – C4 HCs	
68527-16-2	10,000	10,526	2,500	2,632	Negative	Negative	Negative	5,000	5,263	9,000	9,474
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68527-19-5	> 100%	> 100%	2,503	2,632	Positive	Positive	Positive	173,150	>100%	9,009	9,474
	1,3-Butadiene		C1 – C4 HCs		Contains up to 3% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68602-83-5	> 100%	> 100%	2,583	3,597	Positive	Positive	Positive	15,057	138,520	9,298	12,950
	1,3-Butadiene		C1 – C4 HCs		Contains up to 2% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68606-24-6	> 100%	> 100%	2,735	4,464	Positive	Positive	Positive	8,658	40,741	9,847	16,071
	1,3-Butadiene		C1 – C4 HCs		Contains up to 4% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68606-25-7	> 100%	> 100%	2,500	2,525	Positive	Positive	Positive	5,000	5,051	9,000	9,091
	1,3-Butadiene		C1 – C4 HCs		Contains up to 1% 1,3-butadiene			NOAEL†		C1 – C4 HCs	
68606-26-8	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000

Table 13. Petroleum Hydrocarbon Gases Health Effects Data Matrix

CASRN	Endpoint Ranges (ppm)										
	Acute LC_{50}		Repeated-Dose[1]		In vitro Genotoxicity		*In vivo* Genotoxicity	Developmental Toxicity[1]		Reproductive Toxicity[1]	
	Minimum	Maximum[2]	Minimum	Maximum	Bacterial Mutagenicity	Non-bacterial		Minimum	Maximum	Minimum	Maximum
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68606-27-9	> 100%	> 100%	2,503	2,688	Positive	Positive	Positive	173,150	>100%	9,009	9,677
	1,3-Butadiene		C1 – C4 HCs		Contains up to 4% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68606-34-8	430,000	860,000	2,941	3,676	Positive	Positive	Positive	173,150	>100%	10,588	13,235
	1,3-Butadiene		C1 – C4 HCs		Contains up to 30% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68783-61-9	> 100%	> 100%	2,750	4,545	Positive	Positive	Positive	9,113	40,741	9,901	16,364
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.5% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68783-64-2	> 100%	> 100%	2,709	4,545	Positive	Positive	Positive	8,658	45,566	9,751	16,364
	1,3-Butadiene		C1 – C4 HCs		Contains up to 4% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68783-65-3	> 100%	> 100%	2,503	2,660	Positive	Positive	Positive	173,150	> 100%	9,009	9,574
	1,3-Butadiene		C1 – C4 HCs		Contains up to 4% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68918-98-9	10,101	11,765	2,525	2,941	Negative	Negative	Negative	5,051	5,882	9,091	10,588
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68918-99-0	2,953	15,866	2,709	4,630	Negative	Negative	Negative	9,619	51,687	9,751	16,667
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68919-00-6	2531	15,866	2,680	4,310	Negative	Negative	Negative	8,245	51,687	9,646	15,517
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68919-05-1	2,531	15,866	2,680	4,310	Negative	Negative	Negative	8,245	51,687	9,646	15,517
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68919-06-2	10,000	10,204	2,500	2,551	Negative	Negative	Negative	173,150	> 100%	9,000	9,184
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68919-10-8	10,101	11,364	2,525	2,841	Negative	Negative	Negative	173,150	> 100%	9,091	10,227
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68919-16-4	68,500	> 100%	50	1,000	Positive	Positive	Positive	100	2,000	1,500	30,000
	Benzene		Benzene		Contains up to 20% benzene			Benzene		Benzene	

Table 13. Petroleum Hydrocarbon Gases Health Effects Data Matrix

CASRN	Endpoint Ranges (ppm)										
	Acute LC_{50}		Repeated-Dose[1]		In vitro Genotoxicity		*In vivo* Genotoxicity	Developmental Toxicity[1]		Reproductive Toxicity[1]	
	Minimum	Maximum[2]	Minimum	Maximum	Bacterial Mutagenicity	Non-bacterial		Minimum	Maximum	Minimum	Maximum
68919-19-7	10,000	10,204	2,500	2,551	Negative	Negative	Negative	173,150	> 100%	9,000	9,184
	no lethality		C1 – C4 HCs		No genotoxic constituents			C5 – C6 HCs		C1 – C4 HCs	
68919-20-0	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68952-76-1	> 100%	> 100%	2,500	2,634	Positive	Positive	Positive	173,150	>100%	9,000	9,484
	1,3-Butadiene		C1 – C4 HCs		Contains up to 0.1% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68952-81-8	> 100%	> 100%	2,000	> 100%	Positive	Positive	Positive	4,000	> 100%	10,033	27,027
	Benzene		Benzene		Contains up to 0.5% benzene			Benzene		C1 – C4 HCs	
68952-82-9	> 100%	> 100%	2,000	> 100%	Positive	Positive	Positive	4,000	> 100%	10,033	26,087
	Benzene		Benzene		Contains up to 0.5% benzene			Benzene		C1 – C4 HCs	
68955-28-2	215,000	322,500	4,167	6,579	Positive	Positive	Positive	173,150	> 100%	15,000	23,684
	1,3-Butadiene		C1 – C4 HCs		Contains up to 60% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
68955-34-0	10,000	10,000	2,500	2,500	Negative	Negative	Negative	5,000	5,000	9,000	9,000
	no lethality		C1 – C4 HCs		No genotoxic constituents			NOAEL†		C1 – C4 HCs	
68956-54-7	430,000	> 100%	2,778	3,571	Positive	Positive	Positive	3,333	10,000	10,000	12,857
	1,3-Butadiene		C1 – C4 HCs		Contains up to 30% 1,3-butadiene			NOAEL†		C1 – C4 HCs	
71329-37-8	> 100%	> 100%	2,735	4,545	Positive	Positive	Positive	8,658	42,753	9,847	16,364
	1,3-Butadiene		C1 – C4 HCs		Contains up to 5% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	
71808-30-5	> 100%	> 100%	2,577	3,289	Positive	Positive	Positive	18,226	138,520	9,278	11,842
	1,3-Butadiene		C1 – C4 HCs		Contains up to 4% 1,3-butadiene			C5 – C6 HCs		C1 – C4 HCs	

10. Petroleum Hydrocarbon Gases Category Analysis Conclusions

All Hydrocarbon Gases Category members contain primarily hydrocarbons (i.e., alkanes and alkenes) and occasionally asphyxiant gases like hydrogen. The inorganic components of the petroleum hydrocarbon gases are less toxic than the C1 – C4 and C5 – C6 hydrocarbon components to both mammalian and aquatic organisms. Unlike other petroleum product categories (*e.g.* gasoline, diesel fuel, lubricating oils, etc.), the inorganic and hydrocarbon constituents of hydrocarbon gases can be evaluated for hazard individually to then predict the screening level hazard of the Category members. The constituents identified to evaluate Hydrocarbon Gases Category member hazards are:

- Hydrocarbon Gases
    - C1 – C4 Hydrocarbons
    - C5 – C6 Hydrocarbons
    - Benzene
    - 1,3-Butadiene
- Asphyxiant Gases
    - Carbon dioxide
    - Hydrogen gas
    - Nitrogen gas

The majority of components making up hydrocarbon gases typically have low melting and boiling points. They also have high vapor pressures and low octanol/water partition coefficients. The aqueous solubilities of these substances vary, and range from approximately 22 parts per million to several hundred parts per million. The environmental fate characteristics of refinery gases are governed by these physical-chemical attributes. Components of the hydrocarbon gas streams will partition to the air, and photodegradation reactions will be an important fate process for many of the hydrocarbon components. The hydrocarbons in these mixtures are inherently biodegradable, but due to their tendency to partition to the atmosphere, biodegradation is not anticipated to be an important fate mechanisms. However, if released to water or soil, some of the higher molecular weight fractions may become available for microbial attack. The inorganic gases are chemically stable and may be lost to the atmosphere or simply become involved in the environmental cycling of their atoms. Some show substantial water solubility, but their volatility eventually causes these gases to enter the atmosphere.

Acute LC/EC50 values for this constituent group ranged roughly from 1 to 100 mg/L. Although the LC/EC50 data for the individual gases illustrate the potential toxicity to aquatic organisms, aqueous concentrations from atmospheric releases of these gases would not likely attain acute lethal levels. Based on a simple conceptual exposure model analysis, it was shown that atmospheric emissions of hydrocarbon gases would not result in acutely toxic concentrations in adjacent water bodies because such emissions will tend to remain in the atmosphere.

The mammalian health hazards associated with petroleum hydrocarbon gases have been characterized by the seven constituents of the petroleum hydrocarbon gases. The mammalian SIDS endpoint ranges for potential toxicity in the 99 petroleum hydrocarbon gases are conservative because interpretation of hazard study data for the constituents in petroleum hydrocarbon gases has been conservative on the side of over-predicting the potential hazard. Petroleum hydrocarbon gas constituent hazard data were used to characterize SIDS endpoints for each of the 99 petroleum hydrocarbon gases in the category. To accomplish this, the endpoint value (acute LC50, reproductive toxicity NOAEL/LOAEL, etc.) for a specific gas constituent has been adjusted for dilution of each constituent in the respective petroleum hydrocarbon gas. This adjustment for the dilution of each component in a petroleum hydrocarbon gas represents the calculated concentration of the petroleum hydrocarbon gas required to reach the toxicity value (LC_{50}, NOAEL, etc.) corresponding to the pure substance. For example, if the reproductive toxicity LOAEL for neat (100%) benzene is 300 ppm, the LOAEL for a petroleum hydrocarbon gas containing only 2% (wt./v) benzene would be fifty times more than 100% benzene, or 15,000 ppm; *i.e.* at a petroleum hydrocarbon gas concentration of 15,000 ppm, the benzene concentration would be 300 ppm, equal to its reproductive toxicity In many cases, there is more than one potentially toxic constituent in a petroleum hydrocarbon gas. In those cases, the constitutent that is most toxic for a particular endpoint in an individual refinery stream is used to characterize the endpoint hazard for that stream. A more detailed explanation with examples of these calculations, along with the

calculations for each of the 99 petroleum hydrocarbon gases used to determine which constituent to use to characterize mammalian SIDS endpoint-specific hazard for each gas (listed in the Human Health Effects Data Matrix, Table 11) is presented in the body of the document.

This approach to correct for the concentration of the individual petroleum hydrocarbon gas constitutents to estimate the potential toxicity for mammalian endpoints makes it difficult to draw general conclusions as to which constituents are the most hazardous for human health effects of petroleum hydrocarbon gases as a category. The hazard potential for each mammalian endpoint for each of the 99 petroleum hydrocarbon gases is dependent upon each petroleum hydrocarbon gas constituent endpoint toxicity values (LC50, LOAEL, etc.) and the relative concentration of the constituent present in that gas. It should also be noted that for an individual petroleum hydrocarbon gas, the constituent characterizing toxicity may be different for different mammalian endpoints, again, being dependent upon the concentration of the different constituents in each, distinct petroleum hydrocarbon gas.

The human health endpoint ranges of potential toxicity for each of the 99 Petroleum Hydrocarbon Gases Category members are considered adequate for screening level hazard characterization and subsequent screening level risk assessments to be conducted using this information.

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12 LIST OF APPREVIATIONS AND ACRONYMS[1]

AOP – atmospheric oxidation potential
API – American Petroleum Institute
atm-m^3/mole –atmosphere cubic meter per mole
BGVC – basline gasoline vapor condensate
CAS RN/CAS #/CAS No. - Chemical Abstract Service Registry Number
^oC – degrees Celsius
cm^3 – cubic centimeter
CO – carbon monoxide
CO_2 – carbon dioxide
CPK – cratinine phosphokinase
CONCAWE – Conservation of Clean Air and Water in Europe
d - day
DEB – 1,2,3,4-diepoxybutane
DMSO – Dimethyl sulfoxide
EC_{50} – concentration causing a specific response to 50% of the test population
ECB – European Chemicals Bureau
ECG - electrocardiogram
EB – 1,2-epoxy-3-butene
EBD – 1,2-dihydroxy-3,4-epoxybutane
EL_{50} – effective loading rate lethal to 50% of the test population
E_bL_{50} – effective loading rate that causes 50% reduction in algal cell biomass
E_rL_{50} – effective loading rate that causes 50% reduction in algal growth rate
EPA/USEPA – United States Environmental Protection Agency
FOB – functional observational battery
g/cm^3 – grams per cubic centimeter
g/kg – grams per kiligram
g/m^3 – grams per cubic meter
GOT – gutamic oxalacetic transaminase
H_2 – hydrogen
HCs - hydrocarbons
H_2S – hydrogen sulfide
HLS – Huntingdon Life Sciences
hPa - hectopascal
HPV – High Production Volume
hr - hour
IDLH – Immediately Dangerous to Life and Health
^oK – degrees Kelvin
L - liter
LC_{50} – lethal concentration for 50% of the test population
LD_{50}– lethal dose level for 50% of the test population
LDH – lactic dehydrogenase
LL_{50} – lethal loading rate for 50% of the test population
Loading Rate – total amount of test substance added to dilution water to prepare water accommodated fractions (WAFs) for ecotoxicity testing
LOAEL – lowest observable adverse effect level
log Kow – partitian coefficient
m^3 – cubic meter
MACT – maximum achievable control technology
mg/kg – milligrams per kilogram
mg/L – milligrams per liter
mg/m^3 – milligrams per cubic meter

[1] This is a generic list of abbreviations and acronyms; all terms may not appear within this particular document

mL - milliliter
mm - millimeter
N_2 - nitrogen
NH_3 - ammonia
nm - nanometer
NOAEL – no observable adverse effect level
NOEC – no observable effect concentration
NOELR – no observable effect loading rate
OECD – Organization for Economic Cooperation and Development
OPPTS – US EPA Office of Prevention, Pesticides and Toxic Substances
OH^- - hydroxyl radical
PCEs – polychromatic erythrocytes
PII – primary irritation score in skin irritation studies
pO_2 – partial pressure of oxygen
ppm – part per million
RBC – red blood cell
SCE – sister chromatid exchange
SIDS – Screening Information Data Set
SO_2 – sulfur dioxide
TSCA – Toxic Substances Control Act
US EPA – United States Environmental Protection Agency
UV - ultraviolet
WAF – water accommodated fraction
Wt/v% - weight per volume percent µg - microgram
µg/L – microgram/liter
µM - micromole
> greater than
< less than
= equal to

13. GLOSSARY[1]

NOTE: *The following terms are used in this document. To the extent possible definitions were taken from relevant authoritative sources such as US EPA, OECD, ASTM and IUPAC.*

Alpha 2-microglobulin mediated nephropathy: also identified as light hydrocarbon-induced nephropathy (LHN) is a species and sex-specific syndrome induced in male rats resulting from repeated exposure to volatile petroleum naphthas in the gasoline blending stream range. The syndrome is characterized by excessive formation of hyaline droplets comprised of the unique sex-hormone dependent alpha 2-microglobulin, in the epithelium of the proximal convoluted leading to degenerative changes in these tubules in the renal cortex and tubular dilatation and necrosis at the corticomedullary junction. Evaluation of nephrotoxicity of volatile hydrocarbons in male rats and comparison of effects in female rats and both sexes of other species (Alden et al., 1984) has confirmed the uniqueness of this syndrome in male rats and has resulted in the US EPA determination that alpha 2-microglobulin mediated nephrotoxicity is not relevant to health effects in humans. (US EPA, 1991).

Bioavailability: The state of being capable of being absorbed and available to interact with the metabolic processes of an organism. Typically a function of chemical properties, physical state of the material to which an organism is exposed, and the ability of the individual organism to physiologically take up the chemical. Also, the term used for the fraction of the total chemical in the environmental that is available for uptake by organisms. **(AIHA 2000)**

Category Member: The individual chemical or substance entities that constitute a chemical category.

Category: A chemical category, for the purposes of the HPV Challenge Program, is a group of chemicals whose physicochemical and toxicological properties are likely to be similar or follow a regular pattern as a result of structural similarity. These structural similarities may create a predictable pattern in any or all of the following parameters: physicochemical properties, environmental fate and environmental effects, and/or human health effects. **(US EPA 2007b)**

Dose: The amount of a substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism. The **potential dose** is the amount ingested, inhaled, or applied to the skin. The **applied dose** is the amount presented to an absorption barrier and available for absorption (although not necessarily having yet crossed the outer boundary of the organism). The **absorbed dose** is the amount crossing a specific absorption barrier (e.g., the exchange boundaries of the skin, lung, and digestive tract) through uptake processes. **Internal dose** is a more general term denoting the amount absorbed without respect to specific absorption barriers or exchange boundaries. The amount of the chemical available for interaction by a particular organ or cell is termed the delivered or **biologically effective dose** for that organ or cell **(US EPA 2002b).**

Dose-Response Relationship: The relationship between a quantified exposure (dose) and the proportion of subjects demonstrating specific biological changes in incidence or in degree of change (response) **(US EPA 2002b).**

Ecological Effects – all endpoints (OECD definitions)

> **Fish, Acute Toxicity Test:** In a four-day exposure, acute toxicity is defined by the LC_{50}, the concentration of test substance in water which kills 50% of the test population of fish. Test methodology is described in OECD Guideline 203, in OECD Guidelines for the Testing of Chemicals.
>
> ***Daphnia* sp., Acute Immobilization Test:** In a one or two-day exposure, acute toxicity is defined by the EC_{50}, the concentration of test substance in water which causes immobilization to 50% of the test population of invertebrates. Test methodology is described in OECD Guideline 202, Part 1, in OECD Guidelines for the Testing of Chemicals.

[1] This is a generic glossary; all terms may not appear within this particular document

Alga, Growth Inhibition Test: In a three-day exposure, growth inhibition is defined by the EC_{50}, the concentration of test substance in growth medium which results in a 50% reduction in either alga cell growth or growth rate relative to a control group. Test methodology is described in OECD Guideline 201, in OECD Guidelines for the Testing of Chemicals.

Endpoint: In the context of the EPA High Production Volume Challenge Program, an endpoint is a physical-chemical, environmental fate, ecotoxicity, and human health attribute measurable by following an approved test methodology (e.g., OECD Guidelines for Testing of Chemicals). Melting point, biodegradation, fish acute toxicity, and genetic toxicity are examples of endpoints that are measured by an approved test method. **(US EPA 1999)**

Environmental Fate Effects – all endpoints (OECD definitions)

Photodegradation: The photochemical transformation of a molecule into lower molecular weight fragments, usually in an oxidation process. This process may be measured by Draft OECD Guideline, "*Phototransformation of Chemicals in Water – Direct and Indirect Photolysis*". This process also may be estimated using a variety of computer models.

Stability in Water: This environmental fate endpoint is achieved by measuring the hydrolysis of the test substance. Hydrolysis is defined as a reaction of a chemical RX with water, with the net exchange of the group X with OH at the reaction center. Test methodology for hydrolysis is described in OECD Guideline 111, in OECD Guidelines for the Testing of Chemicals.

Transport Between Environmental Compartments: This endpoint describes the distribution of a chemical between environmental compartments using fugacity-based computer models. The results of the model algorithms provide an estimate of the amount of the chemical within a specific compartment. The environmental compartments included in many models are air, water, soil, sediment, suspended sediment, and aquatic biota.

Biodegradation: Breakdown of a substance catalyzed by enzymes *in vitro* or *in vivo*. As an endpoint in EPA's HPV program, biodegradation is measured by one of six methodologies described in OECD Guidelines 301A-F, in OECD Guidelines for the Testing of Chemicals.

Exposure: Contact made between a chemical, physical, or biological agent and the outer boundary of an organism. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut). **(US EPA 2002b).**

Feedstock: A refinery product that is used as the raw material for another process; the term is also generally applied to raw materials used in other industrial processes. **(Speight, 2007).**

Female Mating Index: Number of females with confirmed mating (sperm and/or vaginal plug)/number of females placed with males. (**US EPA 1996).**

Formulated Gasoline: Unleaded automotive fuel formulated by blending paraffinic, olefinic, naphthenic and aromatic petroleum naphtha that does not contain oxygenates (e.g. methyl tertiary butyl ether, ethanol, etc.)**.**

Hazard Assessment: The process of determining whether exposure to an agent can cause an increase in the incidence of a particular adverse health effect (e.g., cancer, birth defect) and whether the adverse health effect is likely to occur in humans **(US EPA 2002b)**.

Hazard Characterization: A description of the potential adverse health effects attributable to a specific environmental agent, the mechanisms by which agents exert their toxic effects, and the associated dose, route, duration, and timing of exposure **(US EPA 2002b).**

Hazard: A potential source of harm **(US EPA 2002b**).

Health Effects – all endpoints (OECD definitions, unless otherwise specified)

Acute Toxicity: The adverse effects occurring within a short time-frame of administration of a single dose of a substance, multiple doses given within 24 hours, or uninterrupted exposure over a period of 24 hours or less. Exposure may be via oral, dermal or inhalation routes as described in OECD Guidelines 401, 402, 403, and 420 in OECD Guidelines for the Testing of Chemicals.

Developmental Toxicity: Adverse effects on the developing organism that may result from exposure prior to conception (either parent), during prenatal development, or postnatally until the time of sexual maturation. The major manifestations of developmental toxicity include death of the developing organism, structural abnormality, altered growth, and functional deficiency. **(US NLM 2007)**

Genetic Toxicity *in vivo* (Chromosomal Aberrations): The assessment of the potential of a chemical to exert adverse effects through interaction with the genetic material of cells in the whole animal. Genotoxicity may be studies in the whole animal using methods described in OECD Guideline 475, in OECD Guidelines for the Testing of Chemicals.

Genetic Toxicity *in vitro* (Gene Mutations): The assessment of the potential of a chemical to exert adverse effects through interaction with the genetic material of cells in cultured mammalian cells. Genotoxicity may be studies in cultured cells using methods described in OECD Guideline 476, in OECD Guidelines for the Testing of Chemicals.

Repeated Dose Toxicity: The adverse effects occurring due to repeated doses that may not produce immediate toxic effects, but due to accumulation of the chemical in tissues or other mechanisms, produces delayed effects. Repeated dose toxicity may be studied following methods described in OECD Guidelines 407, 410, or 412 in OECD Guidelines for the Testing of Chemicals.

Reproductive Toxicity: The occurrence of biologically adverse effects on the reproductive systems of females or males that may result from exposure to environmental agents. The toxicity may be expressed as alterations to the female or male reproductive organs, the related endocrine system, or pregnancy outcomes. The manifestation of such toxicity may include, but not be limited to, adverse effects on onset of puberty, gamete production and transport, reproductive cycle normality, sexual behavior, fertility, gestation, parturition, lactation, developmental toxicity, premature reproductive senescence, or modifications in other functions that are dependent on the integrity of the reproductive systems. **(US EPA 1996)**

Light hydrocarbon induced nephrotoxicity (LHN): also identified as alpha 2-microglobulin mediated nephropathy. See definition above.

Lowest-Observed-Adverse-Effect Level (LOAEL): The lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group **(US EPA 2002b).**

No-Observed-Adverse-Effect Level (NOAEL): The highest exposure level at which there are no biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group; some effects may be produced at this level, but they are not considered adverse or precursors to adverse effects **(US EPA 2002b)**.

Petroleum (crude oil): A naturally occurring mixture of gaseous, liquid, and solid hydrocarbon compounds usually found trapped deep underground beneath impermeable cap rock and above a lower dome of sedimentary rock such as shale; most petroleum reservoirs occur in sedimentary rocks of marine, deltaic, or estuarine origin **(Speight 2007)**.

Portal of Entry Effect: A local effect produced at the tissue or organ of first contact between the biological system and the toxicant **(US EPA 1994b)**.

Read Across: Read-across can be regarded as using data available for some members of a category to estimate values (qualitatively or quantitatively) for category members for which no such data exist. **(OECD 2007)**

Systemic Effects or Systemic Toxicity: Toxic effects as a result of absorption and distribution of a toxicant to a site distant from its entry point **(US EPA 2002b)**.

Target Organ: The biological organ(s) most adversely affected by exposure to a chemical or physical agent **(US EPA 2002b).**

APPENDIX 1

PETROLEUM HYDROCARBON GASES CATEGORY MEMBERS BY CASRN [A,B]

Note A
There are a total of 106 CAS numbers included in the Petroleum Hydrocarbon Gases Category. Of these 106, 92 are listed on the HPV substances list. The Testing Group has included an additional seven CAS numbers that cover substances similar to those on the HPV list. There are also seven supplemental individual chemicals chemicals included in the category that are required to fully characterize the hazards HPV and non-HPV petroleum hydrocarbon gas category members. Category members are presented in these three groups in CASRN order:

- HPV Petroleum Hydrocarbon Gas Category Members
- Non-HPV Petroleum Hydrocarbon Gas Category Members
- Supplemental Chemical Category Members

Note B
The Petroleum HPV Testing Group has included in its listing of CAS numbers an indication of the corresponding category adopted by the European Union (EU) in their legislation (Official Journal of the European Communities, L84 Volume 36, 5 April 1993, *Council Regulation (EEC) No 793/93 of 23 March 1993 on the evaluation and control of risks of existing substances*) and updated by CONCAWE [*Classification and labeling of petroleum substances according to EU dangerous substances directive (CONCAWE recommendations – July 2005)*, Report No. 6/05]. The EU category information is being included in this test plan to facilitate the international harmonization of classification and the coordination of efforts to summarize existing data and develop new hazard data that will be appropriate for hazard and risk characterization worldwide. In doing so, it will help avoid unnecessary duplication of testing.

HPV Petroleum Hydrocarbon Gas Category Members (92 CASRN)

CAS number

000074-82-8
Methane
No definition
(EU Category: none)

000074-84-0[1]
Ethane
No definition
(EU Category: none)

000074-98-6[1]
Propane, liquefied C3H8
No definition
(EU Category: Petroleum Gases)

000075-28-5
Propane, 2-methyl-
No definition
(EU Category: none)

000078-78-4[2]
Butane, 2-methyl
No definition
(EU Category: none)

000106-97-8[3]

[1] Overlaps with ACC Propylene Streams Category
[2] Overlaps with ICCA C5 Aliphatics Category and OECD C5 Aliphatic Hydrocarbon Solvents Category
[3] Overlaps with ACC Low 1,3-Butadiene C4 Category

Butane, pure C4H10
No definition
(EU Category: Petroleum Gases)

000115-07-1[1]
1-Propene
No definition
(EU Category: none)

000287-92-3[2]
Cyclopentane
No definition
(EU Category: none)

000513-35-9[1]
2-Butene, 2-methy-
No definition
(EU Category: none)

008006-14-2
Natural gas
Raw natural gas, as found in nature, or a gaseous combination of hydrocarbons having carbon numbers predominantly in the range of C1 through C4 separated from raw natural gas by the removal of natural gas condensate, natural gas liquid, and natural gas condensate/natural gas.
(EU Category: none)

068131-75-9
Gases (petroleum), C3-4
A complex combination of hydrocarbons produced by distillation of products from the cracking of crude oil. It consists of hydrocarbons having carbon numbers in the range of C3 through C4, predominantly of propane and propylene, and boiling in the range of approximately -51°C to -1°C (-60°F to 30°F).
(EU Category: Petroleum Gases)

068307-98-2
Tail gas (petroleum), catalytic cracked distillate and catalytic cracked naphtha fractionation absorber.
The complex combination of hydrocarbons from the distillation of the products from catalytic cracked distillates and catalytic cracked naphtha. It consists predominantly of hydrocarbons having carbon numbers in the range of C1 through C4.
(EU Category: Petroleum Gases)

068308-03-2
Tail gas (petroleum), gas oil catalytic cracking absorber
A complex combination of hydrocarbons obtained from the distillation of products from the catalytic cracking of gas oil. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.
(EU Category: Petroleum Gases)

068308-04-3
Tail gas (petroleum), gas recovery plant
A complex combination of hydrocarbons from the distillation of products from miscellaneous hydrocarbon streams. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.
(EU Category: Petroleum Gases)

068308-05-4
Tail gas (petroleum), gas recovery plant deethanizer
A complex combination of hydrocarbons from the distillation of products from miscellaneous hydrocarbon streams. It consists of hydrocarbon having carbon numbers predominantly in the range of C1 through C4.

[1] Overlaps with ACC C5 Non-Cyclics Category

(EU Category: Petroleum Gases)

068308-06-5

Tail gas (petroleum), hydrodesulfurized distillate and hydrodesulfurized naphtha fractionator, acid-free

A complex combination of hydrocarbons obtained from fractionation of hydrodesulfurized naphtha and distillate hydrocarbon streams and treated to remove acidic impurities. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.

(EU Category: Petroleum Gases)

068308-08-7

Tail gas (petroleum), isomerized naphtha fractionation stabilizer

A complex combination of hydrocarbons obtained from the fractionation stabilization products from isomerized naphtha. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.

(EU Category: Petroleum Gases)

068308-10-1

Tail gas (petroleum), straight run distillate hydrodesulfurizer, H2S free

A complex combination of hydrocarbons obtained from catalytic hydrodesulfurization of straight run distillates and from which hydrogen sulfide has been removed by amine treatment. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.

(EU Category: Petroleum Gases)

068308-11-2

Tail gas (petroleum), propane-propylene alkylation feed prep deethanizer

A complex combination of hydrocarbons obtained from the distillation of the reaction products of propane with propylene. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.

(EU Category: Petroleum Gases)

068308-12-3

Tail gas (petroleum), vacuum gas oil hydrodesulfurizer, hydrogen sulfide-free

A complex combination of hydrocarbons obtained from catalytic hydrodesulfurization of vacuum gas oil and from which hydrogen sulfide has been removed by amine treatment. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C6.

(EU Category: Petroleum Gases)

068409-99-4

Gases (petroleum), catalytic cracked overheads

A complex combination of hydrocarbons produced by the distillation of products from the catalytic cracking process. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C5 and boiling in the range of approximately -48°C to 32°C (-54°F to 90°F).

(EU Category: Petroleum Gases)

068410-63-9

Natural gas, dried

A complex combination of hydrocarbons separated from natural gas. It consists of saturated aliphatic hydrocarbons having carbon numbers in the range of C1 through C4, predominantly methane and ethane.

(EU Category: none)

068475-58-1

Alkanes, C2-3

No definition

(EU Category: Petroleum Gases)

068475-59-2

Alkanes, C3-4

No definition

(EU Category: Petroleum Gases)

068475-60-5

Alkanes, C4-5

No definition

(EU Category: Petroleum Gases)

068476-40-4

Hydrocarbons, C3-4

No definition

(EU Category: Petroleum Gases)

068476-42-6

Hydrocarbons, C4-5

No definition

(EU Category: Petroleum Gases)

068476-44-8[1]

Hydrocarbons, C4 and higher

No definition

(EU Category: none)

068476-49-3

Hydrocarbons, C2-4, C3-rich

No definition

(EU Category: Petroleum Gases)

068476-54-0

Hydrocarbons, C3-5, polymn. unit feed

A complex combination of hydrocarbons collected from various processes. It consists predominantly of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 to C5 and boiling in the range of approximately –48°C to 38 °C (-54°F to 100°F).

(EU Category: none)

068476-85-7

Petroleum gases, liquefied

A complex combination of hydrocarbons produced by the distillation of crude oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C7 and boiling in the range of approximately -40°C to 80°C (-40°F to 176°F).

(EU Category: Petroleum Gases)

068476-86-8

Petroleum gases, liquefied, sweetened

A complex combination of hydrocarbons obtained by subjecting liquefied petroleum gas mix to a sweetening process to convert mercaptans or to remove acidic impurities. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C7 and boiling in the range of approximately -40°C to 80°C (-40°F to 176°F).

(EU Category: Petroleum Gases)

068477-25-8

Waste gases, vent gas, C1-6

A complex combination of hydrocarbons produced by the distillation of products from the vacuum unit. It consists of saturated hydrocarbons having carbon numbers in the range of C1 through C6.

(EU Category: none)

068477-33-8

Gases (petroleum), C3-4, isobutane-rich

A complex combination of hydrocarbons from the distillation of saturated and unsaturated hydrocarbons usually ranging in carbon numbers from C3 through C6, predominantly butane and isobutane. It consists of saturated and unsaturated hydrocarbons having carbon numbers in the range of C3 through C4, predominantly isobutane.

[1] Overlaps with ACC Crude Butadiene C4 Category

(EU Category: Petroleum Gases)

068477-42-9[1]

Gases (petroleum), extractive, C3-5, butene-isobutylene-rich

A complex combination of hydrocarbons obtained from extractive distillation of saturated and unsaturated aliphatic hydrocarbons usually ranging in carbon numbers from C3 through C5, predominantly C4. It consists of saturated and unsaturated hydrocarbons having carbon numbers predominantly in the range of C3 through C5, predominantly butenes and isobutylene.

(EU Category: none)

068477-69-0

Gases (petroleum), butane splitter overheads

A complex combination of hydrocarbons obtained from the distillation of the butane stream. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 through C4.

(EU Category: Petroleum Gases)

068477-70-3

Gases (petroleum), C2-3

A complex combination of hydrocarbons produced by the distillation of products from a catalytic fractionation process. It contains predominantly ethane, ethylene, propane, and propylene.

(EU Category: Petroleum Gases)

068477-71-4

Gases (petroleum), catalytic-cracked gas oil depropanizer bottoms, C4-rich acid-free

A complex combination of hydrocarbons obtained from fractionation of catalytic cracked gas oil hydrocarbon stream and treated to remove hydrogen sulfide and other acidic components. It consists of hydrocarbons having carbon numbers in the range of C3 through C5, predominantly C4.

(EU Category: Petroleum Gases)

068477-72-5

Gases (petroleum), catalytic-cracked naphtha debutanizer bottoms, C3-5-rich

A complex combination of hydrocarbons obtained from the stabilization of catalytic cracked naphtha. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 through C5.

(EU Category: Petroleum Gases)

068477-73-6

Gases (petroleum), catalytic cracked naphtha depropanizer overhead, C3-rich acid-free

A complex combination of hydrocarbons obtained from fractionation of catalytic cracked hydrocarbons and treated to remove acidic impurities. It consists of hydrocarbons having carbon numbers in the range of C2 through C4, predominantly C3.

(EU Category: Petroleum Gases)

068477-74-7

Gases (petroleum), catalytic cracker

A complex combination of hydrocarbons produced by the distillation of the products from a catalytic cracking process. It consists predominantly of aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C6.

(EU Category: Petroleum Gases)

068477-75-8

Gases (petroleum), catalytic cracker, C1-5-rich

A complex combination of hydrocarbons produced by the distillation of products from a catalytic cracking process. It consists of aliphatic hydrocarbons having carbon numbers in the range of C1 through C6, predominantly C1 through C5.

(EU Category: Petroleum Gases)

068477-79-2

[1] Overlaps with ACC Low 1,3-Butadiene C4 Category

Gases (petroleum), catalytic reformer, C1-4-rich
A complex combination of hydrocarbons produced by distillation of products from a catalytic reforming process. It consists of hydrocarbons having carbon numbers in the range of C1 through C6, predominantly C1 through C4.
(EU Category: Petroleum Gases)

068477-83-8[1]

Gases (petroleum), C3-5 olefinic-paraffinic alkylation feed
A complex combination of olefinic and paraffinic hydrocarbons having carbon numbers in the range of C3 through C5 which are used as alkylation feed. Ambient temperatures normally exceed the critical temperature of these combinations.
(EU Category: Petroleum Gases)

068477-85-0

Gases (petroleum), C4-rich
A complex combination of hydrocarbons produced by distillation of products from a catalytic fractionation process. It consists of aliphatic hydrocarbons having carbon numbers in the range of C3 through C5, predominantly C4.
(EU Category: Petroleum Gases)

068477-86-1

Gases (petroleum), deethanizer overheads
A complex combination of hydrocarbons produced from distillation of the gas and gasoline fractions from the catalytic cracking process. It contains predominantly ethane and ethylene.
(EU Category: Petroleum Gases)

068477-87-2

Gases (petroleum), deisobutanizer tower overheads
A complex combination of hydrocarbons produced by the atmospheric distillation of a butane-butylene stream. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 through C4.
(EU Category: Petroleum Gases)

068477-88-3

Gases (petroleum), deethanizer overheads, C3-rich
A complex combination of hydrocarbons produced by distillation of products from the propylene purification unit. It consists of aliphatic hydrocarbons having carbon numbers in the range of C1 through C3, predominantly C3.
(EU Category: none)

068477-90-7

Gases (petroleum), depropanizer dry, propene-rich
A complex combination of hydrocarbons produced by the distillation of products from the gas and gasoline fractions of a catalytic cracking process. It consists predominantly of propylene with some ethane and propane.
(EU Category: Petroleum Gases)

068477-91-8

Gases (petroleum), depropanizer overheads
A complex combination of hydrocarbons produced by distillation of products from the gas and gasoline fractions of a catalytic cracking process. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C2 through C4.
(EU Category: Petroleum Gases)

068477-94-1

Gases (petroleum), gas recovery plant depropanizer overheads
A complex combination of hydrocarbons obtained by fractionation of miscellaneous hydrocarbon streams. It consists predominantly of hydrocarbons having carbon numbers in the range of C1 through C4, predominantly propane.
(EU Category: Petroleum Gases)

[1] Overlaps with ACC Low 1,3-Butadiene C4 Category

068478-19-3

Residual oils (petroleum), propene purifn. splitter

A complex residuum from the propene purification unit. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 through C4.

(EU Category: none)

068478-24-0

Tail gas (petroleum), catalytic cracker, catalytic reformer and hydrodesulfurizer combined fractionater

A complex combination of hydrocarbons obtained from the fractionation of products from catalytic cracking, catalytic reforming and hydrodesulfurizing processes treated to remove acidic impurities. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.

(EU Category: Petroleum Gases)

068478-26-2

Tail gas (petroleum), catalytic reformed naphtha fractionation stabilizer

A complex combination of hydrocarbons obtained from the fractionation stabilization of catalytic reformed naphtha. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.

(EU Category: Petroleum Gases)

068478-32-0

Tail gas (petroleum), saturate gas plant mixed stream, C4-rich

A complex combination of hydrocarbons obtained from the fractionation stabilization of straight-run naphtha, distillation tail gas and catalytic reformed naphtha stabilizer tail gas. It consists of hydrocarbons having carbon numbers in the range of C3 through C6, predominantly butane and isobutane.

(EU Category: Petroleum Gases)

068478-33-1

Tail gas (petroleum), saturate gas recovery plant, C1-2-rich

A complex combination of hydrocarbons obtained from fractionation of distillate tail gas, straight-run naphtha, catalytic reformed naphtha stabilizer tail gas. It consists predominantly of hydrocarbons having carbon numbers in the range of C1 through C5, predominantly methane and ethane.

(EU Category: Petroleum Gases)

068478-34-2

Tail gas (petroleum), vacuum residues thermal cracker

A complex combination of hydrocarbons obtained from the thermal cracking of vacuum residues. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.

(EU Category: Petroleum Gases)

068512-91-4[1]

Hydrocarbons, C3-4-rich, petroleum distillate

A complex combination of hydrocarbons produced by distillation and condensation of crude oil. It consists of hydrocarbons having carbon numbers in the range of C3 through C5, predominantly C3 through C4.

(EU Category: Petroleum Gases)

068513-12-2

Fuel gases, saturate gas unit fractionater-absorber overheads

A complex combination produced by the fractionation and absorption of products of the saturate gas unit. It consists of hydrogen and saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C4.

(EU Category: none)

068513-15-5

Gases (petroleum), full-range straight-run naphtha dehexanizer off

[1] Overlaps with ACC Crude 1,3-Butadiene C4 Category

A complex combination of hydrocarbons obtained by the fractionation of the full-range straight-run naphtha. It consists of hydrocarbons having carbon numbers predominantly in the range of C2 through C6.
(EU Category: Petroleum Gases)

068513-17-7

Gases (petroleum), light straight-run naphtha stabilizer off
A complex combination of hydrocarbons obtained by the stabilization of light straight-run naphtha. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C2 through C6.
(EU Category: Petroleum Gases)

068513-65-5

Butane, branched and linear
No definition
(EU Category: none)

068513-66-6

Residues (petroleum), alkylation splitter, C4-rich
A complex residuum from the distillation of streams from various refinery operations. It consists of hydrocarbons having carbon numbers in the range of C4 through C5, predominantly butane and boiling in the range of approximately -11.7°C to 27.8°C (11°F to 82°F).
(EU Category: Petroleum Gases)

068514-31-8

Hydrocarbons, C1-4
A complex combination of hydrocarbons produced by thermal cracking and absorber operations and by distillation of crude oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C4 and boiling in the range of approximately -164°C to - 5°C (-263°F to 31°F).
(EU Category: Petroleum Gases)

068514-36-3

Hydrocarbons, C1-4, sweetened
A complex combination of hydrocarbons obtained by subjecting hydrocarbon gases to a sweetening process to convert mercaptans or to remove acidic impurities. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C4 and boiling in the range of approximately -164°C to -0.5°C (-263°F to 31°F).
(EU Category: Petroleum Gases)

068527-16-2

Hydrocarbons, C1-3
A complex combination of hydrocarbons having carbon numbers predominantly in the range of C1 through C3 and boiling in the range of approximately minus 164°C to -42°C (-263°F to -44°F).
(EU Category: Petroleum Gases)

068527-19-5[1]

Hydrocarbons, C1-4, debutanizer fraction
No definition
(EU Category: Petroleum Gases)

068602-83-5

Gases (petroleum), C1-5, wet
A complex combination of hydrocarbons produced by the distillation of crude oil and/or the cracking of tower gas oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.
(EU Category: Petroleum Gases)

068606-24-6[2]

[1] Overlaps with ACC C5 Non-Cyclics Category
[2] Overlaps with ACC Low 1,3-Butadiene C4 Category

Hydrocarbons, C4, butene concentrator by-product
A complex combination of hydrocarbons obtained in the production of butene concentrate. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C5.
(EU Category: none)

068606-25-7
Hydrocarbons, C2-4
No definition
(EU Category: Petroleum Gases)

068606-26-8[1]
Hydrocarbons, C3
No definition
(EU Category: Petroleum Gases)

068606-27-9
Gases (petroleum), alkylation feed
A complex combination of hydrocarbons produced by the catalytic cracking of gas oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C4.
(EU Category: Petroleum Gases)

068606-34-8
Gases (petroleum), depropanizer bottoms fractionation off
A complex combination of hydrocarbons obtained from the fractionation of depropanizer bottoms. It consists predominantly of butane, isobutane and butadiene.
(EU Category: Petroleum Gases)

068783-61-9
Fuel gases, refinery, sweetened
A complex combination obtained by subjecting refinery fuel gases to a sweetening process to convert mercaptans or to remove acidic impurities. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5 and boiling in the range of approximately -73^{o}C to 50^{o}C (-100^{o}F to 122^{o}F).
(EU Category: none)

068783-64-2
Gases (petroleum), catalytic cracking
A complex combination of hydrocarbons produced by the distillation of the products from a catalytic cracking process. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C3 through C5.
(EU Category: Petroleum Gases)

068783-65-3
Gases (petroleum), C2-4, sweetened
A complex combination of hydrocarbons obtained by subjecting a petroleum distillate to a sweetening process to convert mercaptans or to remove acidic impurities. It consists predominantly of saturated and unsaturated hydrocarbons having carbon numbers predominantly in the range of C2 through C4 and boiling in the range of approximately -51°C to -34°C (-60°F to -30°F).
(EU Category: Petroleum Gases)

068918-98-9
Fuel gases, refinery, hydrogen sulfide-free
A complex combination of light gases consisting of hydrocarbons having carbon numbers predominantly in the range of C1 through C3. Produced from the fractionation and subsequent scrubbing of hydrotreating units.
(EU Category: none)

068918-99-0
Gases (petroleum), crude oil fractionation off

[1] Overlaps with ACC Propylene Streams Category

A complex combination of hydrocarbons produced by the fractionation of crude oil. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C5.
(EU Category: Petroleum Gases)

068919-05-1

Gases (petroleum), light straight run gasoline fractionation stabilizer off
A complex combination of hydrocarbons obtained by the fractionation of light straight-run gasoline. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C5.
(EU Category: Petroleum Gases)

068919-06-2

Gases (petroleum), naphtha unifiner desulfurization stripper off
A complex combination of hydrocarbons produced by a naphtha unifiner desulfurization process and stripped from the naphtha product. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C4.
(EU Category: Petroleum Gases)

068919-10-8

Gases (petroleum), straight-run stabilizer off
A complex combination of hydrocarbons obtained from the fractionation of the liquid from the first tower used in the distillation of crude oil. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C4.
(EU Category: Petroleum Gases)

068919-16-4

Hydrocarbons, C3-6, catalytic alkylation by-products
The complex combination of hydrocarbons obtained by the catalytic alkylation of benzene with propylene. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C6 and boiling in the range of approximately -40°C to 70°C (-40°F to 158°F). This stream may contain 1 to 20 vol. % of benzene.
(EU Category: none)

068919-19-7

Gases (petroleum), fluidized catalytic cracker splitter residues
A complex combination of hydrocarbons produced by the fractionation of the charge to the C3-C4 splitter. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C3 through C4.
(EU Category: none)

068919-20-0

Gases (petroleum), fluidized catalytic cracker splitter overheads
A complex combination of hydrocarbons produced by the fractionation of the charge to the C3-C4 splitter. It consists predominantly of C3 hydrocarbons.
(EU Category: Petroleum Gases)

068952-76-1

Gases (petroleum), catalytic cracked naphtha debutanizer
A complex combination of hydrocarbons obtained from fractionation of catalytic cracked naphtha. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.
(EU Category: none)

068952-81-8

Tail gas (petroleum), thermal-cracked distillate, gas oil and naphtha absorber
A complex combination of hydrocarbons obtained from the separation of thermal-cracked distillates, naphtha and gas oil. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C6.
(EU Category: Petroleum Gases)

068952-82-9

Tail gas (petroleum), thermal cracked hydrocarbon fractionation stabilizer, petroleum coking

A complex combination of hydrocarbons obtained from the fractionation stabilization of thermal cracked hydrocarbons from petroleum coking process. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C6.
(EU Category: Petroleum Gases)

068955-28-2[1]

Gases (petroleum), light steam-cracked, butadiene conc.
A complex combination of hydrocarbons produced by the distillation of products from a thermal cracking process. It consists of hydrocarbons having a carbon number predominantly of C4.
(EU Category: Petroleum Gases)

068955-34-0

Gases (petroleum), straight-run naphtha catalytic reformer stabilizer overhead
A complex combination of hydrocarbons obtained by the catalytic reforming of straight-run naphtha and the fractionation of the total effluent. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C2.
(EU Category: Refinery Gases, Category 2)

068956-54-7[1]

Hydrocarbons, C4-unsatd.
No definition
(EU Category: none)

071329-37-8

Residues (petroleum), catalytic cracking depropanizer, C4-rich
A complex residuum from the stabilization of catalytic cracked naphtha hydrocarbon streams. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C3 through C5, primarily C4.
(EU Category: none)

071808-30-5

Tail gas (petroleum), thermal cracking absorber
A complex combination of hydrocarbons obtained from the separation of thermal cracked naphtha, distillates and gas oil hydrocarbons. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.
(EU Category: none)

[1] Overlaps with ACC Crude 1,3-Butadiene C4 Category

Non-HPV Petroleum Hydrocarbon Gas Category Members (7 CASRN)

CAS number

000109-66-0[21]

Pentane
No definition
(EU Category: none)

068307-99-3

Tail gas (petroleum), catalytic polymn. naphtha fractionation stabilizer
A complex combination of hydrocarbons from the fractionation stabilization products from polymerization of naphtha. It consists predominantly of hydrocarbons having carbon numbers in the range of C1 through C4.
(EU Category: Petroleum Gases)

068308-02-1

Tail gas (petroleum), distn., hydrogen sulfide-free
No definition
(EU Category: none)

068308-09-8

Tail gas (petroleum), light straight-run naphtha stabilizer, hydrogen sulfide-free
A complex combination of hydrocarbons obtained from fractionation stabilization of light straight run naphtha and from which hydrogen sulfide has been removed by amine treatment. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.
(EU Category: Petroleum Gases)

068475-57-0

Alkanes, C1-2
No definition
(EU Category: Petroleum Gases)

068477-76-9

Gases (petroleum), catalytic polymd. naphtha stabilizer overhead, C2-4-rich
A complex combination of hydrocarbons obtained from the fractionation stabilization of catalytic polymerized naphtha. It consists of aliphatic hydrocarbons having carbon numbers in the range of C2 through C6, predominantly C2 through C4.
(EU Category: Petroleum Gases)

068919-00-6

Gas (petroleum), dehexanizer off
A complex combination of hydrocarbons obtained by the fractionation of combined naphtha streams. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C5.
(EU Category: Petroleum Gases)

[1] Overlaps with ICCA C5 Aliphatics Category and OECD C5 Aliphatic Hydrocarbon Solvents Category

Supplemental Chemical Category Members (7 CASRN)

CAS number

000071-43-2
Benzene
No definition
(EU Category: none)

000106-98-9
1-Butene
No Definition
(EU Category: none)

000106-99-0
1,3-Butadiene
No definition
(EU Category: none)

000107-01-7
2-Butene
No definition
(EU Category: none)

000124-38-9
Carbon dioxide
No definition
(EU Category: none)

001333-74-0
Hydrogen
No definition
(EU Category: none)

007727-37-9
Nitrogen
No definition
[EU Category: none]

APPENDIX 2

Petroleum Hydrocarbon Gases Category Member Component Concentration Ranges by CASRN

Sources of Composition Data Concerning the Petroleum Hydrocarbon Gases

The petroleum process streams designated as Petroleum Hydrocarbon Gases are normally site-limited intermediates or waste materials, not products for commercial sale, and definitely not "finished" to meet formal specifications. These streams contain one or more inorganic compounds with variable concentrations and at least one component with high enough concentration to be toxic and/or cause oxygen depletion in a closed space.

The compositions provided in this table of Petroleum Hydrocarbon Gases are based upon limited historical (1992 through 2002) data from several US petrochemical and petroleum company refineries in the Gulf Coast and Mid-continent areas. These facilities processed mostly heavy (high viscosity), sour (high sulfur content) crude oils of Venezuelan and Mexican origin. These compositions did not necessarily reflect the concentration ranges for streams with the same Chemical Abstract Service Registry Numbers (CASRN) for East and West Coast refineries or other refineries processing light viscosity or sweet crude oils. Current sample analyses may not be representative of the average concentration ranges displayed because regulatory control of sulfur- and nitrogen-containing compounds is much more stringently controlled by enhanced processing, especially at West Coast refineries. Although these compositional ranges for the inorganic constituents, benzene, and butadiene of these particular Petroleum Hydrocarbon Gases are considered to err on the side of higher, rather than lower concentrations, they are considered to be plausible, and have been used to derive petroleum hydrocarbon gas toxicity values that have been corrected for concentration.

Gas chromatography and/or mass spectrophotometer analysis of these Petroleum Hydrocarbon Gas streams is not done for routine (daily, weekly, or monthly) process control purposes. Test samples are collected only when specific questions arise. Examples of reasons for non-routine compositional testing include temporary on-site storage, off-site transfer (via pipeline), corrosion control, planned process modifications, Material Safety Data Sheet (MSDS) creation or update, and/or the addition or modification of environmental monitoring and control equipment.

Concentration ranges of specific gas components may vary drastically depending upon crude oil sources, operating conditions, seasonal process issues, and economic cycles. The inorganic constituents identified in these Petroleum Hydrocarbon Gas streams include hydrogen, ammonia, hydrogen sulfide, methyl mercaptan, ethyl mercaptan, carbon monoxide, and carbon dioxide. If nitrogen is present at significant levels in the stream, it was also included because of its' oxygen replacement property. No effort was made to identify individual hydrocarbon compound ranges present in these streams. The complex hydrocarbon mixture component is identified only by its carbon number range for the total mixtures, C1 – C4 and C5 – C6. In several streams containing C4 through C6 hydrocarbons, the presence of a few potentially carcinogenic hydrocarbon components (butadiene and benzene at concentrations exceeding 0.1 wt.%) has been included, even though they are not identified in the Petroleum Hydrocarbon Gas stream's CASRN definition.

The compositional ranges for the 99 petroleum hydrocarbon gases are presented below in two different organizational formats to make finding specific information easier for the reader. Appendix Table 2-1 presents the gases component concentrations by CASRN, Gas Name, and TSCA Definition. To more easily see what components are present in each petroleum hydrocarbon stream, and at what concentration ranges, the same data presented in Appendix Table 2.1 is presented in Appendix Table 2.2, which follows Appendix Table 2.1.

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
74-82-8	Methane	No definition.	C1-C4 = 79 to 99%; Hydrogen = 1 to 20%; Nitrogen = 0 to 1%
74-84-0	Ethane	No definition.	C1-C4 = 100%
74-98-6	Propane, liquefied C3H8	No definition.	C1-C4 = 100%
75-28-5	Propane, 2-methyl-	No definition.	C1-C4 = 100%
78-78-4	Butane, 2-methyl-	No definition.	C5-C6 = 100%
106-97-8	Butane, pure C4H10	No definition.	C1-C4 = 100%
109-66-0	Pentane	No definition.	C5-C6 = 100%
115-07-1	1-Propene	No definition.	C1-C4 = 100%
287-92-3	Cyclopentane	No definition.	C5-C6 = 100%
513-35-9	2-Butene, 2-methyl-	No definition.	C5-C6 = 100%
8006-14-2	Natural gas	Raw natural gas, as found in nature, or a gaseous combination of hydrocarbons having carbon numbers predominantly in the range of C1 through C4 separated from raw natural gas by the removal of natural gas condensate, natural gas liquid, and natural gas condensate/natural gas.	C1-C4 = 89.5 to 94.9%; Hydrogen = 5 to 10%; Nitrogen = 0.1 to 0.5%
68131-75-9	Gases (petroleum), C3-4	A complex combination of hydrocarbons produced by distillation of products from the cracking of crude oil. It consists of hydrocarbons having carbon numbers in the range of C3 through C4, predominantly of propane and propylene, and boiling in the range of approximately -51°C to -1°C (-60°F to 30°F).	C1-C4 = 99.9 to 100%; 1,3-Butadiene = 0 to 0.1%
68307-98-2	Tail gas (petroleum), catalytic cracked distillate and catalytic cracked naphtha fractionation absorber	The complex combination of hydrocarbons from the distillation of the products from catalytic cracked distillates and catalytic cracked naphtha. It consists predominantly of hydrocarbons having carbon numbers in the range of C1 through C4.	C1-C4 = 96.5 to 99.9%; C5-C6 = 0 to 1%; Hydrogen = 0 to 2%; Carbon dioxide = 0 to 0.5%; Butadiene = 0.1 to 2%

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68307-99-3	Tail gas (petroleum), catalytic polymn. naphtha fractionation stabilizer	A complex combination of hydrocarbons from the fractionation stabilization products from polymerization of naphtha. It consists predominantly of hydrocarbons having carbon numbers in the range of C1 through C4.	C1-C4 = 92 to 99.4%. C5-C6 = 0 to 1%; Hydrogen = 0.5 to 5%; Butadiene = 0.1 to 2%
68308-02-1	Tail gas (petroleum), distn., hydrogen sulfide-free	No definition.	C1-C4 = 64.5 to 83.5%; C5-C6 = 1.5 to 5.5%; Hydrogen = 15% to 30%
68308-03-2	Tail gas (petroleum), gas oil catalytic cracking absorber	A complex combination of hydrocarbons obtained from the distillation of products from the catalytic cracking of gas oil. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 86 to 98.3%; C5-C6 = 1.7 to 10.5%; Hydrogen = 0% to 3%; Carbon dioxide = 0 to 0.5%
68308-04-3	Tail gas (petroleum), gas recovery plant	A complex combination of hydrocarbons from the distillation of products from miscellaneous hydrocarbon streams. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 88.5 to 98.2%; C5-C6 = 1.7 to 8%; Hydrogen = 0.1% to 3%; Carbon dioxide = 0 to 0.5%
68308-05-4	Tail gas (petroleum), gas recovery plant deethanizer	A complex combination of hydrocarbons from the distillation of products from miscellaneous hydrocarbon streams. It consists of hydrocarbon having carbon numbers predominantly in the range of C1 through C4.	C1-C4 = 97 to 99.9%; C5-C6 = 0 to 1%; Butadiene = 0.1 to 2%
68308-06-5	Tail gas (petroleum), hydrodesulfurized distillate and hydrodesulfurized naphtha fractionator, acid-free	A complex combination of hydrocarbons obtained from fractionation of hydrodesulfurized naphtha and distillate hydrocarbon streams and treated to remove acidic impurities. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 82 to 98%; C5-C6 = 2 to 18%
68308-08-7	Tail gas (petroleum), isomerized naphtha fractionation stabilizer	A complex combination of hydrocarbons obtained from the fractionation stabilization products from isomerized naphtha. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.	C1-C4 = 99 to 100%; C5-C6 = 0 to 1%

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68308-09-8	Tail gas (petroleum), light straight-run naphtha stabilizer, hydrogen sulfide-free	A complex combination of hydrocarbons obtained from fractionation stabilization of light straight run naphtha and from which hydrogen sulfide has been removed by amine treatment. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 82 to 98%; C5-C6 = 2 to 18%
68308-10-1	Tail gas (petroleum), straight run distillate hydrodesulfurizer, H2S free	A complex combination of hydrocarbons obtained from catalytic hydrodesulfurization of straight run distillates and from which hydrogen sulfide has been removed by amine treatment. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.	C1-C4 = 98 to 100%; C5-C6 = 0 to 2%
68308-11-2	Tail gas (petroleum), propane-propylene alkylation feed prep deethanizer	A complex combination of hydrocarbons obtained from the distillation of the reaction products of propane with propylene. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.	C1-C4 = 100%
68308-12-3	Tail gas (petroleum), vacuum gas oil hydrodesulfurizer, hydrogen sulfide-free	A complex combination of hydrocarbons obtained from catalytic hydrodesulfurization of vacuum gas oil and from which hydrogen sulfide has been removed by amine treatment. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C6.	C1-C4 = 26 to 84.9%; C5-C6 = 15.1 to 73%; Benzene = 0 to 1% (C7 included in C5-C6; C7 = 0 to 1%)
68409-99-4	Gases (petroleum), catalytic cracked overheads	A complex combination of hydrocarbons produced by the distillation of products from the catalytic cracking process. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C5 and boiling in the range of approximately -48°C to 32°C (-54°F to 90°F).	C1-C4 = 65 to 93%; C5-C6 = 7 to 31%; Hydrogen = 0 to 3%; Carbon dioxide = 0 to 1%; Butadiene = 0.5 to 4%

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68410-63-9	Natural gas, dried	A complex combination of hydrocarbons separated from natural gas. It consists of saturated aliphatic hydrocarbons having carbon numbers in the range of C1 through C4, predominantly methane and ethane.	C1-C4 = 89.5 to 94.9%; Hydrogen = 5 to 10%; Nitrogen = 0.1 to 0.5%
68475-57-0	Alkanes, C1-2	No definition.	C1-C4 = 98 to 100%; Hydrogen = 0 to 2%
68475-58-1	Alkanes, C2-3	No definition.	C1-C4 = 100%
68475-59-2	Alkanes, C3-4	No definition.	C1-C4 = 100%
68475-60-5	Alkanes, C4-5	No definition.	C1-C4 = 35 to 65%; C5-C6 = 35 to 65%
68476-40-4	Hydrocarbons, C3-4	No definition.	C1-C4 = 99 to 100%; C5-C6 = 0 to 1%
68476-42-6	Hydrocarbons, C4-5	No definition.	C1-C4 = 33 to 67%; C5-C6 = 33 to 67%
68476-44-8	Hydrocarbons, C4 and higher	No definition.	C1-C4 = 16.2 to 51%; C5-C6 = 49 to 83.8 %; Benzene = 0 to 1% (C7 and C8 included in C5-C6; C7 = 1.6 to 15%; C8 = 0 to 1%)
68476-49-3	Hydrocarbons, C2-4, C3-rich	No definition.	C1-C4 = 100%
68476-54-0	Hydrocarbons, C3-5, polymn. unit feed	A complex combination of hydrocarbons collected from various processes. It consists predominantly of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 to C5 and boiling in the range of approximately -48°C to 38°C (-54°F to 100°F).	C1-C4 = 61 to 84.5%; C5-C6 = 15.5 to 39%; Butadiene = 0 to 0.5%
68476-85-7	Petroleum gases, liquefied	A complex combination of hydrocarbons produced by the distillation of crude oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C7 and boiling in the range of approximately -40°C to 80°C (-40°F to 176°F).	C1-C4 = 17.2 to 61%; C5-C6 = 37 to 82.7%; Butadiene = 0 to 0.1%; Benzene = 0 to 1%; Mercaptans = 0.1 - 1% (C7 and C8 included in C5-C6; C7 = 2.6 to 17%; C8 = 0 to 2%)

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition

CAS Number	Petroleum Hydrocarbon Gas Name	TSCA Definition	Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)
68476-86-8	Petroleum gases, liquefied, sweetened	A complex combination of hydrocarbons obtained by subjecting liquefied petroleum gas mix to a sweetening process to convert mercaptans or to remove acidic impurities. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C7 and boiling in the range of approximately -40°C to 80°C (-40°F to 176°F).	C1-C4 = 17.2 to 61%; C5-C6 = 39 to 82.8%; Butadiene = 0 to 0.1%; Benzene = 0 to 1% (C7 and C8 included in C5-C6; C7 = 2.6 to 17%; C8 = 0 to 2%)
68477-25-8	Waste gases, vent gas, C1-6	A complex combination of hydrocarbons produced by the distillation of products from the vacuum unit. It consists of saturated hydrocarbons having carbon numbers in the range of C1 through C6.	C1-C4 = 33 to 77.9%; C5-C6 = 22.1 to 64%; Hydrogen = 0 to 2%; Benzene = 0 to 1% (C7 included in C5-C6; C7 = 0 to 1%)
68477-33-8	Gases (petroleum), C3-4, isobutane-rich	A complex combination of hydrocarbons from the distillation of saturated and unsaturated hydrocarbons usually ranging in carbon numbers from C3 through C6, predominantly butane and isobutane. It consists of saturated and unsaturated hydrocarbons having carbon numbers in the range of C3 through C4, predominantly isobutane.	C1-C4 = 76.5 to 96%; C5-C6 = 4 to 22%; Butadiene = 0 to 1%; Benzene = 0 to 0.5%
68477-42-9	Gases (petroleum), extractive, C3-5, butene-isobutylene-rich	A complex combination of hydrocarbons obtained from extractive distillation of saturated and unsaturated aliphatic hydrocarbons usually ranging in carbon numbers from C3 through C5, predominantly C4. It consists of saturated and unsaturated hydrocarbons having carbon numbers predominantly in the range of C3 through C5, predominantly butenes and isobutylene.	C1-C4 = 82.5 to 97%; C5-C6 = 3 to 16.5%; Butadiene = 0 to 0.1%
68477-69-0	Gases (petroleum), butane splitter overheads	A complex combination of hydrocarbons obtained from the distillation of the butane stream. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 through C4.	C1-C4 = 98 to 100%; C5-C6 = 0 to 2%

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68477-70-3	Gases (petroleum), C2-3	A complex combination of hydrocarbons produced by the distillation of products from a catalytic fractionation process. It contains predominantly ethane, ethylene, propane, and propylene.	C1-C4 = 100%
68477-71-4	Gases (petroleum), catalytic-cracked gas oil depropanizer bottoms, C4-rich acid-free	A complex combination of hydrocarbons obtained from fractionation of catalytic cracked gas oil hydrocarbon stream and treated to remove hydrogen sulfide and other acidic components. It consists of hydrocarbons having carbon numbers in the range of C3 through C5, predominantly C4.	C1-C4 = 68 to 93%; C5-C6 = 7 to 32%; Butadiene = 0.5 to 4%
68477-72-5	Gases (petroleum), catalytic-cracked naphtha debutanizer bottoms, C3-5-rich	A complex combination of hydrocarbons obtained from the stabilization of catalytic cracked naphtha. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 through C5.	C1-C4 = 60 to 84.5%; C5-C6 = 15.5 to 40%; Butadiene = 0 to 0.5%
68477-73-6	Gases (petroleum), catalytic cracked naphtha depropanizer overhead, C3-rich acid-free	A complex combination of hydrocarbons obtained from fractionation of catalytic cracked hydrocarbons and treated to remove acidic impurities. It consists of hydrocarbons having carbon numbers in the range of C2 through C4, predominantly C3.	C1-C4 = 99 to 100%; C5-C6 = 0 to 1%; Butadiene = 0.1 to 2%
68477-74-7	Gases (petroleum), catalytic cracker	A complex combination of hydrocarbons produced by the distillation of the products from a catalytic cracking process. It consists predominantly of aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C6.	C1-C4 = 39.5 to 90.2%; C5-C6 = 9.8 to 57.5%; Hydrogen = 0 to 2%; Carbon dioxide = 0 to 1%; Benzene = 0 to 0.5% (C7 included in C5-C6; C7 = 0.5 to 2%)
68477-75-8	Gases (petroleum), catalytic cracker, C1-5-rich	A complex combination of hydrocarbons produced by the distillation of products from a catalytic cracking process. It consists of aliphatic hydrocarbons having carbon numbers in the range of C1 through C6, predominantly C1 through C5.	C1-C4 = 49.8 to 91.8%; C5-C6 = 8.2 to 47%; Hydrogen = 0 to 2%; Carbon dioxide = 0 to 1%; Benzene = 0 to 0.2%

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68477-76-9	Gases (petroleum), catalytic polymd. naphtha stabilizer overhead, C2-4-rich	A complex combination of hydrocarbons obtained from the fractionation stabilization of catalytic polymerized naphtha. It consists of aliphatic hydrocarbons having carbon numbers in the range of C2 through C6, predominantly C2 through C4.	C1-C4 = 73 to 95.3%; C5-C6 = 4.7 to 27%
68477-79-2	Gases (petroleum), catalytic reformer, C1-4-rich	A complex combination of hydrocarbons produced by distillation of products from a catalytic reforming process. It consists of hydrocarbons having carbon numbers in the range of C1 through C6, predominantly C1 through C4.	C1-C4 = 87.3 to 97.2%; C5-C6 = 2.8 to 12.5%; Benzene = 0 to 0.2%
68477-83-8	Gases (petroleum), C3-5 olefinic-paraffinic alkylation feed	A complex combination of olefinic and paraffinic hydrocarbons having carbon numbers in the range of C3 through C5 which are used as alkylation feed. Ambient temperatures normally exceed the critical temperature of these combinations.	C1-C4 = 58.5 to 88.4%; C5-C6 = 11.6 to 39.5%; Butadiene = 0 to 2%
68477-85-0	Gases (petroleum), C4-rich	A complex combination of hydrocarbons produced by distillation of products from a catalytic fractionation process. It consists of aliphatic hydrocarbons having carbon numbers in the range of C3 through C5, predominantly C4.	C1-C4 = 74 to 98.5%; C5-C6 = 1.5 to 25.5%; Butadiene = 0 - 0.5%
68477-86-1	Gases (petroleum), deethanizer overheads	A complex combination of hydrocarbons produced from distillation of the gas and gasoline fractions from the catalytic cracking process. It contains predominantly ethane and ethylene.	C1-C4 = 93 to 100%; Hydrogen = 0 to 5%; Carbon dioxide = 0 to 2%
68477-87-2	Gases (petroleum), deisobutanizer tower overheads	A complex combination of hydrocarbons produced by the atmospheric distillation of a butane-butylene stream. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 through C4.	C1-C4 = 94 to 100%, C5-C6 = 0 to 5%; Butadiene = 0 - 1%
68477-88-3	Gases (petroleum), deethanizer overheads, C3-rich	A complex combination of hydrocarbons produced by distillation of products from the propylene purification unit. It consists of aliphatic hydrocarbons having carbon numbers in the range of C1 through C3, predominantly C3.	C1-C4 = 95 to 100%; Hydrogen = 0 to 5%

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68477-90-7	Gases (petroleum), depropanizer dry, propene-rich	A complex combination of hydrocarbons produced by the distillation of products from the gas and gasoline fractions of a catalytic cracking process. It consists predominantly of propylene with some ethane and propane.	C1-C4 = 93 to 100%; Hydrogen = 0 to 5%; Carbon dioxide = 0 to 2%
68477-91-8	Gases (petroleum), depropanizer overheads	A complex combination of hydrocarbons produced by distillation of products from the gas and gasoline fractions of a catalytic cracking process. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C2 through C4.	C1-C4 = 86 to 99%; C5-C6 = 1 to 5%; Hydrogen = 0 - 5%; Carbon dioxide = 0 - 2%Butadiene = 0 to 2%
68477-94-1	Gases (petroleum), gas recovery plant depropanizer overheads	A complex combination of hydrocarbons obtained by fractionation of miscellaneous hydrocarbon streams. It consists predominantly of hydrocarbons having carbon numbers in the range of C1 through C4, predominantly propane.	C1-C4 = 94.5 to 100%; Hydrogen = 0 to 5%; Butadiene = 0 to 0.5%
68478-19-3	Residual oils (petroleum), propene purifn. splitter	A complex residuum from the propene purification unit. It consists of aliphatic hydrocarbons having carbon numbers predominantly in the range of C3 through C4.	C1-C4 = 95 to 99.5%; C5-C6 = 0.5 to 5%
68478-24-0	Tail gas (petroleum), catalytic cracker, catalytic reformer, and hydrodesulfurizer combined fractionater	A complex combination of hydrocarbons obtained from the fractionation of products from catalytic cracking, catalytic reforming, and hydrodesulfurizing processes treated to remove acidic impurities. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 67.9 to 93.3%; C5-C6 = 6.7 to 28%; Hydrogen = 0 to 3%; Carbon dioxide = 0 to 1%; Butadiene = 0 to 0.1%
68478-26-2	Tail gas (petroleum), catalytic reformed naphtha fractionation stabilizer	A complex combination of hydrocarbons obtained from the fractionation stabilization of catalytic reformed naphtha. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.	C1-C4 = 91.9 to 99.5%; C5-C6 = 0.5 to 5%; Hydrogen = 0 to 3%; Butadiene = 0 to 0.1

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68478-32-0	Tail gas (petroleum), saturate gas plant mixed stream, C4-rich	A complex combination of hydrocarbons obtained from the fractionation stabilization of straight-run naphtha, distillation tail gas and catalytic reformed naphtha stabilizer tail gas. It consists of hydrocarbons having carbon numbers in the range of C3 through C6, predominantly butane and isobutane.	C1-C4 = 67.5 to 96.7%; C5-C6 = 3.3 to 31%; Butadiene = 0 to 1%; Benzene = 0 to 0.5% (C7 included in C5-C6; C7 = 0 to 2%)
68478-33-1	Tail gas (petroleum), saturate gas recovery plant, C1-2-rich	A complex combination of hydrocarbons obtained from fractionation of distillate tail gas, straight-run naphtha, and catalytic reformed naphtha stabilizer tail gas. It consists predominantly of hydrocarbons having carbon numbers in the range of C1 through C5, predominantly methane and ethane.	C1-C4 = 75.5 to 93.5%; C5-C6 = 1.5 to 4.5%; Hydrogen = 5 to 20%
68478-34-2	Tail gas (petroleum), vacuum residues thermal cracker	A complex combination of hydrocarbons obtained from the thermal cracking of vacuum residues. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 73 to 97%; C5-C6 = 2.5 to 19%; Hydrogen = 0 to 3%; Carbon dioxide = 0 to 1%; Butadiene = 0.5 to 4%
68512-91-4	Hydrocarbons, C3-4-rich, petroleum distillate	A complex combination of hydrocarbons produced by distillation and condensation of crude oil. It consists of hydrocarbons having carbon numbers in the range of C3 through C5, predominantly C3 through C4.	C1-C4 = 74 to 98.5%; C5-C6 = 1.5 to 25.5%; Butadiene = 0 - 0.5%
68513-12-2	Fuel gases, saturate gas unit fractionater-absorber overheads	A complex combination produced by the fractionation and absorption of products of the saturate gas unit. It consists of hydrogen and saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C4.	C1-C4 = 67 to 89.9%; C5-C6 = 0.1 to 3%; Hydrogen = 10 to 30%
68513-15-5	Gases (petroleum), full-range straight-run naphtha dehexanizer off	A complex combination of hydrocarbons obtained by the fractionation of the full-range straight-run naphtha. It consists of hydrocarbons having carbon numbers predominantly in the range of C2 through C6.	C1-C4 = 36.5 to 82.4%; C5-C6 = 17.6 to 63%; Benzene = 0 to 0.5 (C7 included in C5-C6; C7 = 0 to 1%)

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68513-17-7	Gases (petroleum), light straight-run naphtha stabilizer off	A complex combination of hydrocarbons obtained by the stabilization of light straight-run naphtha. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C2 through C6.	C1-C4 = 34 to 82.4%; C5-C6 = 17.6 to 66% (C7 included in C5-C6; C7 = 0 to 1%)
68513-65-5	Butane, branched and linear	No definition.	C1-C4 = 97.5 to 100%; C5-C6 = 0 to 2%; Butadiene = 0 to 0.5%
68513-66-6	Residues (petroleum), alkylation splitter, C4-rich	A complex residuum from the distillation of streams from various refinery operations. It consists of hydrocarbons having carbon numbers in the range of C4 through C5, predominantly butane and boiling in the range of approximately -11.7°C to 27.8°C (11°F to 82°F).	C1-C4 = 68.5 to 89%; C5-C6 = 11 to 31%; Butadiene = 0 to 0.5
68514-31-8	Hydrocarbons, C1-4	A complex combination of hydrocarbons produced by thermal cracking and absorber operations and by distillation of crude oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C4 and boiling in the range of approximately -164°C to - 5°C (-263°F to 31°F).	C1-C4 = 92 to 99.8%; Hydrogen = 0 to 3%; Carbon dioxide = 0 to 1%; Mercaptans = 0.1 to 1%; Butadiene = 0.1 to 3%
68514-36-3	Hydrocarbons, C1-4, sweetened	A complex combination of hydrocarbons obtained by subjecting hydrocarbon gases to a sweetening process to convert mercaptans or to remove acidic impurities. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C4 and boiling in the range of approximately -164° C to -0.5°C (-263°F to 31°F).	C1-C4 = 97 to 99.9%; Butadiene = 0.1 to 3%
68527-16-2	Hydrocarbons, C1-3	A complex combination of hydrocarbons having carbon numbers predominantly in the range of C1 through C3 and boiling in the range of approximately -164°C to -42°C (-263°F to -44° F).	C1-C4 = 95 to 100%; Hydrogen = 0 to 5%
68527-19-5	Hydrocarbons, C1-4, debutanizer fraction	No definition.	C1-C4 = 95 to 99.9%; C5-C6 = 0 to 2%; Butadiene = 0.1 to 3%

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68602-83-5	Gases (petroleum), C1-5, wet	A complex combination of hydrocarbons produced by the distillation of crude oil and/or the cracking of tower gas oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 69.5 to 96.8%; C5-C6 = 2.5 to 23%; Hydrogen = 0.5 to 5%; Nitrogen = 0.1 to 0.5%; Butadiene = 0.1 to 2%
68606-24-6	Hydrocarbons, C4, butene concentrator by-product	A complex combination of hydrocarbons obtained in the production of butene concentrate. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C5.	C1-C4 = 56 to 91.4%; C5-C6 = 8.5 to 40%; Butadiene = 0.1 to 4%
68606-25-7	Hydrocarbons, C2-4	No definition.	C1-C4 = 99 to 100%; Butadiene = 0 to 1%
68606-26-8	Hydrocarbons, C3	No definition.	C1-C4 = 100%
68606-27-9	Gases (petroleum), alkylation feed	A complex combination of hydrocarbons produced by the catalytic cracking of gas oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C4.	C1-C4 = 93 to 99.9%; C5-C6 = 0 to 2%; Carbon dioxide = 0 to 1%; Butadiene = 0.1 to 4%
68606-34-8	Gases (petroleum), depropanizer bottoms fractionation off	A complex combination of hydrocarbons obtained from the fractionation of depropanizer bottoms. It consists predominantly of butane, isobutane and butadiene.	C1-C4 = 68 to 85%; C5-C6 = 0 to 2%; Butadiene = 15 to 30%
68783-61-9	Fuel gases, refinery, sweetened	A complex combination obtained by subjecting refinery fuel gases to a sweetening process to convert mercaptans or to remove acidic impurities. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C5 and boiling in the range of approximately -73°C to 50°C (-100°F to 122°F).	C1-C4 = 55 to 90.9%; C5-C6 =8.5 to 38%; Hydrogen = 0.5 to 5%; Nitrogen = 0.1 to 0.5%; Carbon dioxide = 0 - 1%; Butadiene = 0 to 0.5%
68783-64-2	Gases (petroleum), catalytic cracking	A complex combination of hydrocarbons produced by the distillation of the products from a catalytic cracking process. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C3 through C5.	C1-C4 = 55 to 92.3%; C5-C6 =7.6 to 40%; Carbon dioxide = 0 to 1%; Butadiene = 0.1 to 4%

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68783-65-3	Gases (petroleum), C2-4, sweetened	A complex combination of hydrocarbons obtained by subjecting a petroleum distillate to a sweetening process to convert mercaptans or to remove acidic impurities. It consists predominantly of saturated and unsaturated hydrocarbons having carbon numbers predominantly in the range of C2 through C4 and boiling in the range of approximately -51°C to -34°C (-60°F to -30°F).	C1-C4 = 94 to 99.9%; C5-C6 = 0 to 2%; Butadiene = 0.1 to 4%
68918-98-9	Fuel gases, refinery, hydrogen sulfide-free	A complex combination of light gases consisting of hydrocarbons having carbon numbers predominantly in the range of C1 through C3. Produced from the fractionation and subsequent scrubbing of hydrotreating units.	C1-C4 = 85 to 99%; Hydrogen = 1 to 15%
68918-99-0	Gases (petroleum), crude oil fractionation off	A complex combination of hydrocarbons produced by the fractionation of crude oil. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 54 to 92.3%; C5-C6 = 6.7 to 36%; Hydrogen = 1 to 10%
68919-00-6	Gas (petroleum), dehexanizer off	A complex combination of hydrocarbons obtained by the fractionation of combined naphtha streams. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 58 to 93.3%; C5-C6 = 6.7 to 42%
68919-05-1	Gases (petroleum), light straight run gasoline fractionation stabilizer off	A complex combination of hydrocarbons obtained by the fractionation of light straight-run gasoline. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 58 to 93.3%; C5-C6 = 6.7 to42 %
68919-06-2	Gases (petroleum), naphtha unifiner desulfurization stripper off	A complex combination of hydrocarbons produced by a naphtha unifiner desulfurization process and stripped from the naphtha product. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C4.	C1-C4 = 98 to 100%; C5-C6 = 0 to 2%

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68919-10-8	Gases (petroleum), straight-run stabilizer off	A complex combination of hydrocarbons obtained from the fractionation of the liquid from the first tower used in the distillation of crude oil. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C1 through C4.	C1-C4 = 88 to 99%; C5-C6 = 0 to 2%; Hydrogen = 1 to 10%
68919-16-4	Hydrocarbons, C3-6, catalytic alkylation by-products	The complex combination of hydrocarbons obtained by the catalytic alkylation of benzene with propylene. It consists of hydrocarbons having carbon numbers predominantly in the range of C3 through C6 and boiling in the range of approximately -40°C to 70°C (-40°F to 158°F). This stream may contain 1 to 20 vol.% of benzene.	C1-C4 = 20.9 to 85.7%; C5-C6 = 13.3 to 78.1%; Benzene = 1 to 20% (C7 included in C5-C6; C7 = 0 to 2%)
68919-19-7	Gases (petroleum), fluidized catalytic cracker splitter residues	The complex combination of hydrocarbons produced by the fractionation of the charge to the C3-C4 splitter. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C3 through C4.	C1-C4 = 98 to 100%; C5-C6 =0 to 2%
68919-20-0	Gases (petroleum), fluidized catalytic cracker splitter overheads	The complex combination of hydrocarbons produced by the fractionation of the charge to the C3-C4 splitter. It consists predominantly of C3 hydrocarbons.	C1-C4 = 100%
68952-76-1	Gases (petroleum), catalytic cracker naphha debutanizer	The complex combination of hydrocarbons obtained from fractionation of catalytic cracked naphtha. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C4.	C1-C4 = 94.9 to 100%; C5-C6 = 0 to 2%; Hydrogen = 0 to 3%; Butadiene = 0 to 0.1%
68952-81-8	Tail gas (petroleum), thermal-cracked distillate, gas oil and naphtha absorber	A complex combination of hydrocarbons obtained from the separation of thermal-cracked distillates, naphtha, and gas oil. It consists of predominantly of hydrocarbons having carbon numbers predominantly in the range of C1 through C6.	C1-C4 = 33.3 to 89.7%; C5-C6 = 10.3 to 65.5%; Hydrogen = 0 to 3%; Carbon dioxide = 0 to 1%; Benzene = 0 to 0.5% (C7 included in C5-C6; C7 = 0.5 to 2%)
68952-82-9	Tail gas (petroleum), thermal cracked hydrocarbon fractionation stabilizer, petroleum coking	A complex combination of hydrocarbons obtained from the fractionation stabilization of thermal cracked hydrocarbons from petroleum coking process. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C6.	C1-C4 = 34.5 o 89.7%; C5-C6 = 10.3 to 65.5%; Benzene = 0 to 0.5% (C7 included in C5-C6; C7 = 0.5 to 2%)

Appendix Table 2-1. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN, Gas Name, and TSCA Definition			
CAS Number	**Petroleum Hydrocarbon Gas Name**	**TSCA Definition**	**Petroleum Hydrocarbon Gases Composition Ranges (wt/v%)**
68955-28-2	Gases (petroleum), light steam-cracked, butadiene conc.	A complex combination of hydrocarbons produced from distillation of products from a thermal cracking process. It consists of hydrocarbons having carbon number predominantly of C4.	C1-C4 = 38 to 60%; C5-C6 = 0 to 2%; Butadiene = 40 to 60%
68955-34-0	Gases (petroleum), straight-run naphtha catalytic reformer stabilizer overhead	A complex combination of hydrocarbons obtained from catalytic reforming of straight-run naphtha and the fractionation of total effluent. It consists of saturated aliphatic hydrocarbons having carbon numbers predominantly in the range of C2.	C1-C4 = 100%
68956-54-7	Hydrocarbons, C4-unsatd.	No definition.	C1-C4 = 70 to 90%; Butadiene = 10 to 30%
71329-37-8	Residues (petroleum), catalytic cracking depropanizer, C4-rich	A complex residuum from the stabilization of catalytic cracked naphtha hydrocarbon streams. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C3 through C5, primarily C4.	C1-C4 = 55 to 91.4%; C5-C6 = 8.1 to 40%; Butadiene = 0.5 to 5%
71808-30-5	Tail gas (petroleum), thermal cracking absorber	A complex combination of hydrocarbons obtained from the separation of thermal cracked naphtha, distillates, and gas oil hydrocarbons. It consists of hydrocarbons having carbon numbers predominantly in the range of C1 through C5.	C1-C4 = 76 to 97%; C5-C6 =2.5 to 19%; Carbon dioxide = 0 to 1%; Butadiene = 0.5 to 4%

To more easily see what components are present in each refinery stream, and at what concentration ranges, the same data presented in Appendix Table 2.1 (above) is presented by CASRN and constituent components in Appendix Table 2.2 below.

Appendix Table 2-2. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN and Component Ranges

CASRN	Component Compositional Ranges[1] (Wt. %)						
	Hydrocarbons				Asphyxiant Gases		
	Hydrocarbons C1 – C4	Hydrocarbons C5 – C6 (light naphthas)	Benzene 71-43-2	1,3-Butadiene 106-99-2	Hydrogen 1333-74-0	Nitrogen 7727-37-9	Carbon dioxide 124-38-9
74-82-8	79 - 99				1 - 20	0 - 1	
74-84-0	100						
74-98-6	100						
75-28-5	100						
78-78-4		100					
106-97-8	100						
109-66-0		100					
115-07-1	100						
287-92-3		100					
513-35-9		100					
8006-14-2	89.5 - 94.9				5 - 10	0.1 - 0.5	
68131-75-9	99.9 - 100			0 – 0.1			
68307-98-2	96.5 – 99.9	0 - 1		0.1 - 2	0 - 2		0 – 0.5
68307-99-3	92 – 99.4	0 - 1		0.1 - 2	0.5 - 5		
68308-02-1	64.5 – 83.5	1.5 – 5.5			15 - 30		
68308-03-2	86 – 98.3	1.7 – 10.5			0 - 3		0 – 0.5
68308-04-3	88.5 – 98.2	1.7 – 8			0.1 - 3		0 – 0.5
68308-05-4	97 – 99.9	0 - 1		0.1- 2			
68308-06-5	82 - 98	2 - 18					
68308-08-7	99 - 100	0 - 1					
68308-09-8	82 - 98	2 -18					
68308-10-1	98 - 100	0 - 2					

[1] a blank cell indicates that the component is not present in that stream.

Appendix Table 2-2. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN and Component Ranges

CASRN		Component Compositional Ranges[1] (Wt. %)					
	Hydrocarbons				Asphyxiant Gases		
	Hydrocarbons C1 – C4	Hydrocarbons C5 – C6 (light naphthas)	Benzene 71-43-2	1,3-Butadiene 106-99-2	Hydrogen 1333-74-0	Nitrogen 7727-37-9	Carbon dioxide 124-38-9
68308-11-2	100						
68308-12-3	26 – 84.9	15.1 - 73[2]	0 - 1				
68409-99-4	65 - 93	7 - 31		0.5 - 4	0 - 3		0 - 1
68410-63-9	89.5 – 94.9				5 - 10	0.1 – 0.5	
68475-57-0	98 - 100				0 - 2		
68475-58-1	100						
68475-59-2	100						
68475-60-5	35 - 65	35 - 65					
68476-40-4	99 - 100	0 - 1					
68476-42-6	33 - 67	33 - 67					
68476-44-8	16.2 - 51	49 – 83.8[3]	0 - 1				
68476-49-3	100						
68476-54-0	61 – 84.5	15.5 - 39		0 – 0.5			
68476-85-7	17.2 - 61	37 – 82.7[4]	0 - 1	0 – 0.1			
68476-86-8	17.2 - 61	39 – 82.8	0 - 1	0 – 0.1			
68477-25-8	33 - 77.9	22.1 - 64[5]	0 - 1		0 - 2		
68477-33-8	76.5 - 96	4 – 22	0 – 0.5	0 – 1			
68477-42-9	82.5 - 97	3 – 16.5		0 – 0.1			
68477-69-0	98 - 100	0 - 2					
68477-70-3	100						
68477-71-4	68 - 93	7 - 32		0.5 - 4			
68477-72-5	60 – 84.5	15.5 – 40		0 – 0.5			
68477-73-6	99 - 100	0 - 1		0. 1 - 2			
68477-74-7	39.5 - 90.2	9.8 – 57.5[6]	0 – 0.5		0 - 2		0 - 1

[2] C7 included in C5-C6 fraction; C7= 0 to 1%
[3] C7 and C8 included in C5-C6 fraction; C7= 1.6 to 15%; C8 = 0 to 1%
[4] C7 and C8 included in C5-C6 fraction; C7= 2.6 to 17%; C8 = 0 to 2%
[5] C7 included in C5-C6 fraction; C7= 0 to 1%

Appendix Table 2-2. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN and Component Ranges

CASRN		Component Compositional Ranges[1] (Wt. %)					
	Hydrocarbons				Asphyxiant Gases		
	Hydrocarbons C1 – C4	Hydrocarbons C5 – C6 (light naphthas)	Benzene 71-43-2	1,3-Butadiene 106-99-2	Hydrogen 1333-74-0	Nitrogen 7727-37-9	Carbon dioxide 124-38-9
68477-75-8	49.8 – 91.8	8.2 – 47	0 – 0.2		0 - 2		0 - 1
68477-76-9	73 – 95.3	4.7 - 27					
68477-79-2	87.3 – 97.2	2.8 – 12.5	0 – 0.2				
68477-83-8	58.5 – 88.4	11.6 – 39.5		0 - 2			
68477-85-0	74 – 98.5	1.5 – 25.5		0 – 0.5			
68477-86-1	93 - 100				0 - 5		0 - 2
68477-87-2	94 - 100	0 - 5		0 - 1			
68477-88-3	95 - 100				0 - 5		
68477-90-7	93 - 100				0 - 5		0 - 2
68477-91-8	86 -99	1 - 5		0 - 2	0 - 5		0 - 2
68477-94-1	94.5 - 100			0 – 0.5	0 - 5		
68478-19-3	95 – 99.5	0.5 - 5					
68478-24-0	67.9 – 93.3	6.7 - 28		0 – 0.1	0 - 3		0 - 1
68478-26-2	91.9 – 99.5	0.5 - 5		0 – 0.1	0 - 3		
68478-32-0	67.5 – 96.7	3.3 - 31[7]	0 – 0.5	0 - 1			
68478-33-1	75.5 – 93.5	1.5 – 4.5			5 - 20		
68478-34-2	73 - 97	2.5 - 19		0.5 - 4	0 - 3		0 - 1
68512-91-4	74 – 98.5	1.5 – 25.5		0 – 0.5			
68513-12-2	67 – 89.9	0.1 - 3			10 - 30		
68513-15-5	36.5 – 82.4	17.6 – 63[8]	0 – 0.5				
68513-17-7	34 – 82.4	17.6 - 66[9]					
68513-65-5	97.5 - 100	0 - 2		0 – 0.5			
68513-66-6	68.5 - 89	11 - 31		0 – 0.5			
68514-31-8	92 – 99.8			0.1 - 3	0 - 3		0 - 1
68514-36-3	97 – 99.9			0.1 - 3			

[6] C7 included in C5-C6 fraction; C7= 0.5 to 2%
[7] C7 included in C5-C6 fraction; C7= 0 to 2%
[8] C7 included in C5-C6 fraction; C7= 0 to 1%
[9] C7 included in C5-C6 fraction; C7= 0 to 1%

Appendix Table 2-2. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN and Component Ranges							
CASRN		**Component Compositional Ranges[1] (Wt. %)**					
	Hydrocarbons				**Asphyxiant Gases**		
	Hydrocarbons C1 – C4	**Hydrocarbons C5 – C6 (light naphthas)**	**Benzene 71-43-2**	**1,3-Butadiene 106-99-2**	**Hydrogen 1333-74-0**	**Nitrogen 7727-37-9**	**Carbon dioxide 124-38-9**
68527-16-2	95 - 100				0 - 5		
68527-19-5	95 – 99.9	0 - 2		0.1 - 3			
68602-83-5	69.5 – 96 8	2.5 - 23		0.1 - 2	0.5 - 5	0.1 – 0.5	
68606-24-6	56 – 91.4	8.5 - 40		0.1 - 4			
68606-25-7	99 - 100			0 - 1			
68606-26-8	100						
68606-27-9	93 – 99.9	0 - 2		0.1 - 4			0 - 1
68606-34-8	68 - 85	0 - 2		15 - 30			
68783-61-9	55 – 90.9	8.5 - 38		0 – 0.5	0.5 - 5	0.1 – 0.5	0 - 1
68783-64-2	55 – 92.3	7.6 - 40		0.1 - 4			0 - 1
68783-65-3	94 – 99.9	0 - 2		0.1 - 4			
68918-98-9	85 - 99				1 - 15		
68918-99-0	54 – 92.3	6.7 - 36			1 - 10		
68919-00-6	58 – 93.3	6.7 - 42					
68919-05-1	58 – 93.3	6.7 - 42					
68919-06-2	98 - 100	0 - 2					
68919-10-8	88 - 99	0 - 2			1 - 10		
68919-16-4	20.9 – 85.7	13.3 – 78.1[10]	1 - 20				
68919-19-7	98 - 100	0 - 2					
68919-20-0	100						
68952-76-1	94.9 - 100	0 - 2		0 – 0.1	0 - 3		
68952-81-8	33.3 – 89.7	10.3 – 65.5[11]	0 – 0.5		0 - 3		0 - 1
68952-82-9	34.5 – 89.7	10.3 – 65.5[12]	0 – 0.5				
68955-28-2	38 - 60	0 - 2		40 - 60			
68955-34-0	100						

[10] C7 included in C5-C6 fraction; C7= 0 to 2%

[11] C7 included in C5-C6 fraction; C7= 0.5 to 2%
[12] C7 included in C5-C6 fraction; C7= 0.5 to 2%

Appendix Table 2-2. Component Concentration Ranges for Petroleum Hydrocarbon Gases by CASRN and Component Ranges							
CASRN		**Component Compositional Ranges[1] (Wt. %)**					
	Hydrocarbons				**Asphyxiant Gases**		
	Hydrocarbons C1 – C4	**Hydrocarbons C5 – C6 (light naphthas)**	**Benzene 71-43-2**	**1,3-Butadiene 106-99-2**	**Hydrogen 1333-74-0**	**Nitrogen 7727-37-9**	**Carbon dioxide 124-38-9**
68956-54-7	70 - 90			10 - 30			
71329-37-8	55 – 91.4	8.1 - 40		0.5 - 5			
71808-30-5	76 – 97	2.5 - 19		0.5 - 4			0 - 1

Appendix 3

Key Studies for Petroleum Hydrocarbon Gases Hydrocarbon and Inorganic Constituents

ACUTE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LC50/LD50**	**Reference**	**Comments**
C1-C4 (2-Butene has lowest LC50 for this category)	107-07-7	Inhalation	Rat	>10,000 ppm	Arts, JHE. 1992. Acute (4-hour) inhalation toxicity study of butene-2 in rats. Report No. V92.183/352130. TNO Nutrition and Food Research, Zeist, The Netherlands. [2butene]	OECD limit test
methane ethane ethylene propane propylene n-butane isobutane 1,3-butadiene isobutylene	74-82-8 74-84-0 74-85-1 74-98-6 115-07-1 106-97-8 75-28-5 106-99-0 115-11-7	Aqueous	fish invertebrate algae	6.3 ppm – 137 ppm 7.2 ppm – 138 ppm 4.7 ppm – 82 ppm	EPA (U.S. Environmental Protection Agency). 2000. EPI Suite™, the Estimation Programs Interface (EPI) Suite™. U.S. Environmental Protection Agency, Washington, DC.	Ranges of values represent structure-activity modelling using the ECOSAR Program in EPI Suite™. Chemical list includes C1-C4 compounds methane, ethane, propane, butane, isobutane, and 1,3-butadiene. .

ACUTE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LC50/LD50**	**Reference**	**Comments**
C5-C6	Several; see gasoline blending streams Category Analysis Document, 2008	Inhalation	Rat	LC50>1063 ppm	API (American Petroleum Institute) 1980. Acute toxicity tests. API PS-6 unleaded motor gasoline. API Rpt #27-32130, Washington, DC. API (American Petroleum Institute) 1984. Acute inhalation toxicity evaluation of a petroleum derived hydrocarbon in rats. API 83-05 Full range catalytic reformed naphtha. API Rpt. #31-30681. Washington, DC. API (American Petroleum Institute) 1987a. Acute inhalation toxicity evaluation of a petroleum derived hydrocarbon in rats. API 83-19 Light alkylate naphtha. API Rpt. #34-30636. Washington, DC. API (American Petroleum Institute) 1987b. Acute inhalation toxicity evaluation of a petroleum derived hydrocarbon in rats. API 83-20 Light catalytic cracked naphtha. API Rpt. #34-32777. Washington, DC. API (American Petroleum Institute) 1987c. Acute inhalation toxicity evaluation of a petroleum derived hydrocarbon in rats. API 81-08 Sweetened naphtha. API Rpt #33-31827. Washington, DC.	Weight of evidence from four gasoline blending streams (high paraffinic stream, high olefinic stream , high naphthenic stream, and high aromatic stream) plus wholly vaporized gasoline)
pentane isopentane cyclopentane isopentene cyclopentene hexane isohexane cyclohexane	109-66-0 78-78-4 287-92-3 563-45-1 142-29-0 110-54-3 107-83-5 110-82-7	Aqueous	fish invertebrate algae	1.0 ppm – 18 ppm 1.3 ppm – 20 ppm 0.9 ppm – 13 ppm	EPA (U.S. Environmental Protection Agency). 2000. EPI Suite™, the Estimation Programs Interface (EPI) Suite™. U.S. Environmental Protection Agency, Washington, DC.	Ranges of values represent structure-activity modelling using the ECOSAR Program in EPI Suite™. Chemical list includes C5-C6 compounds pentane and hexane.

ACUTE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LC50/LD50**	**Reference**	**Comments**
Nitrogen	7727-37-9	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
Hydrogen	1333-74-0	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
Carbon Dioxide	124-38-9	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.

ACUTE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LC50/LD50**	**Reference**	**Comments**
1,3-Butadiene	106-99-0	Inhalation	Rat	129,000 ppm (4 hr)	Shugaev, BB. 1969. Concentrations of hydrocarbons in tissues as a measure of toxicity. Arch. Environ. Health 18:878882.	Study used to support IDLH.
		Aqueous	Fish Invertebrate Algae	38 ppm 40 ppm 25 ppm	EPA (U.S. Environmental Protection Agency). 2000. EPI Suite™, the Estimation Programs Interface (EPI) Suite™. U.S. Environmental Protection Agency, Washington, DC.	
Benzene	71-43-2	Inhalation	Rat	13,700 ppm (4 hr)	Drew RT and JR Fouts. 1974. The lack of effects of pretreatment with phenobarbital and chlorpromazine on the acute toxicity of benzene in rats. Toxicol Appl Pharmacol 27:183-193.	

ACUTE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LC50/LD50**	**Reference**	**Comments**
		Aqueous	Fish	5.3 ppm – 35.7 ppm	DeGraeve, GM, Elder, RG, Woods, DC and HL Bergman. 1982. Effects of naphthalene and benzene on fathead minnows and rainbow trout. Arch. Environ. Contam. Toxicol. 11(4):487-490. Brooke, L. 1987. Acute Test Comparisons with Fathead Minnows and Acute Tests with an Amphipod and a Cladoceran. Centre for Lake Superior Environmental Studies, University of Wisconsin – Superior, Wisconsin. 24 p.	
			Invertebrate	59.6 ppm – 682 ppm	MacLean, MM. and KG Doe. 1989. The Comparative Toxicity of Crude and Refined Oils to Daphnia magna and Artemia. Environment Canada, EE-111, Dartmouth, Nova Scotia. 64 p. Eastmond, D.A., G.M. Booth, and M.L. Lee. 1984. Toxicity, Accumulation, and Elimination of Polycyclic Aromatic Sulfur Heterocycles in Daphnia magna. Arch. Environ. Contam.Toxicol. 13(1):105-111.	
			Algae	29 ppm	Galassi, SM, Mingazzini, L, . Vigano, D, Cesaeeo, and ML Tosato. 1988. Approaches to Modeling the Toxic Responses of Aquatic Organisms to Aromatic Hydrocarbons. Ecotoxicol. Environ. Saf. 16(2):158-169.	

REPEAT DOSE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LOAEL/ Duration**	**Reference**	**Comments**
C1-C4 (2-Butene has lowest LOAEL for this group of consituents)	107-07-7	Inhalation	Rat	5000 ppm/ 39-46 days	Waalkens-Brendsen, DH. and JHE Arts. 1992. Combined short term inhalation and reproductive/developmental toxicity screening test with Butene-2 in rats. Proj. #B91-8336 (Study #1410) [2-butene].	Body weight decrease
C5-C6	Several; see gasoline blending streams Category Analysis Document, 2008	Inhalation	Rat	6625 ppm/ 13 weeks	API (American Petroleum Institute) 2005a. Baseline Gasoline Vapor Condensate A 13 week whole body inhalation toxicity Study in Rats with Neurotoxicity Assessments and 4-week In Vivo Genotoxicty and Immunotoxicity Assessments. HLS Study No. 00-6125. Huntingdon Life Sciences Laboratories, East Millstone, NJ.	
Nitrogen	7727-37-9	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.

REPEAT DOSE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LOAEL/ Duration**	**Reference**	**Comments**
Hydrogen	1333-74-0	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
Carbon Dioxide	124-38-9	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.

REPEAT DOSE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LOAEL/ Duration**	**Reference**	**Comments**
1,3-Butadiene	106-99-0	Inhalation	Rat	8000 ppm / 105 wks	Owen, PE. 1981. The toxicity and carcinogenicity of butadiene gas administered to rats by inhalation for approximately 24 months. Report No. 2653-522/2. Harrogate, Hazleton Laboratories Europe Ltd. (Confidential report prepared for the International Institute of Synthetic Rubber Producers Inc., New York, USA). Owen PE and JR Glaister. 1990. Inhalation toxicity and carcinogenicity of 1,3-butadiene in Sprague-Dawley rats. Environ Health Persp. **86;** 19-25. Owen PE, Glaister, JR, Gaunt, IF, and DH Pullinger.1987. Inhalation toxicity studies with 1,3-butadiene. 3. Two year toxicity/ carcinogenicity study in rats. Am Ind Hyg Assoc J. **48;** 407-413.	Note: butadiene classified as a human carcinogen
Benzene	71-43-2	Inhalation	Mice	≤10 ppm/ 50 days	Green, JD, Snyder, CA, LoBue J, Goldstein, BD, and RE Albert. 1981. Acute and chronic dose/response effect of benzene inhalation on the peripheral blood, bone marrow, and spleen cell of CD-1 male mice. Toxicol Appl Pharmacol 59:204-214.	Increases in splenic weight and cellularity.

IN VITRO GENETIC TOXICITY					
Component	**CAS No.**	**Assay**	**Results**	**Reference**	**Comments**
C1-C4	Various; see Appendix 4	All non mammalian and mammalian systems tested	Negative	See Appendix 4.	
C5-C6	Several; see gasoline blending streams Category Analysis Document, 2008	Non-mammalian Mammalian	Negative Negative	API (American Petroleum Institute) 1977a. Mutagenicity evaluation of unleaded gasoline (L5178Y Mouse lymphoma assay and Ames test) API Rpt #28-30173 Washington, DC. [report includes single ip dose *in vivo* cytogenetic assay].	
Nitrogen	7727-37-9	No specific data; considered a simple asphyxiant		McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
Hydrogen	1333-74-0	No specific data; considered a simple asphyxiant		McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.

***IN VITRO* GENETIC TOXICITY**					
Component	**CAS No.**	**Assay**	**Results**	**Reference**	**Comments**
Carbon Dioxide	124-38-9	No specific data; considered a simple asphyxiant		McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
1,3-Butadiene	106-99-0	Non-mammalian Mammalian	Positive Weakly positive	Arce, GT, Vincent, DR, Cunningham, MJ Choy, WN and AM Sarrif. 1990. *In vitro* and *in vivo* genotoxicity of 1,3-butadiene and metabolites. Environ. Health Perspect. 86:75-8. Sasiadek, M, Järventaus, H and M Sorsa. 1991. Sister-chromatid exchanges induced by 1,3-butadiene and its epoxides in CHO cells. *Mutat Res*. **263;** 47-50.	Several studies conducted; In general, the mammalian studies were poorly reported or had flaws, but consensus appears that material is weakly positive with metabolic activation. Representative studies used for robust summary.
Benzene	71-43-2	Non-mammalian Mammalian	Many negative, but one positive Positive	Glatt, H, Padykula, R, Berchtold, GA, Ludwig, G, Platt, KL, Klein, J and F Oesch. 1989. Multiple activation pathways of benzene leading to products with varying genotoxic characteristics. Environ Health Perspect 82:81-89. Morimoto K. 1983. Induction of sister chromatid exchanges and cell division delays in human lymphocytes by microsomal activation of benzene. Cancer Res 43:1330-1334.	Multiple studies; Representative positive studies used for robust summary.

IN VIVO GENETIC TOXICITY					
Component	**CAS No.**	**Assay**	**Results**	**Reference**	**Comments**
C1-C4	Various; see Appendix 4	All non mammalian and mammalian systems tested	Negative	See Appendix 4.	
C5-C6	Several; see gasoline blending streams Category Analysis Document, 2008	Micronuclei formation, rats	Negative	API (American Petroleum Institute) 2005b. Baseline Gasoline Vapor Condensate. Micronucleus Assay in a 13 week Whole Body Inhalation Toxicity Study in Rats with Neurotoxicity Assessments and 4-week In Vivo Genotoxicity and Immunotoxicity Assessments. HLS Study No. 00-6125, Vol IV, Appendix X. Huntingdon Life Sciences Laboratories, East Millstone, NJ and Huntingdon Eye Research Center, Suffolk, UK. API (American Petroleum Institute) 2005c. Baseline Gasoline Vapor Condensate. Sister Chromatid Exchange Assay in a 13 week Whole Body Inhalation Toxicity Study in Rats with Neurotoxicity Assessments and 4-week In Vivo Genotoxicity and Immunotoxicity Assessments. HLS Study No. 00-6125, Vo. IV, Appendix Y. Huntingdon Life Sciences Laboratories, East Millstone, NJ and BioReliance Laboratories, Rockville, MD.	

***IN VIVO* GENETIC TOXICITY**					
Component	**CAS No.**	**Assay**	**Results**	**Reference**	**Comments**
Nitrogen	7727-37-9	No specific data; considered a simple asphyxiant		McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
Hydrogen	1333-74-0	No specific data; considered a simple asphyxiant		McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
Carbon Dioxide	124-38-9	No specific data; considered a simple asphyxiant		McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.

***IN VIVO* GENETIC TOXICITY**					
Component	**CAS No.**	**Assay**	**Results**	**Reference**	**Comments**
1,3-Butadiene	106-99-0	Micronuclei formation, mice	Positive	Autio, K, Renzi, L, Catalan, J, Albrecht, OE, and M Sorsa. 1994. Induction of micronuclei in peripheral blood and bone marrow erythrocytes of rats and mce exposed to 1,3-butadiene by inhalation. Mut. Res. 309:315-320.	Inhalation, mice, 500 ppm = maximum concentration tested. KS=1. Studies conducted on crude butadiene streams were also positive. Same study was negative in rats.
Benzene	71-43-2	Sister chromatid exchange and blood micronuclei formation, mice	Positive	Erexson, GL, Wilmer, JL, Steinhagen, WH, and AD Kilgerman. 1986. Induction of Cytogenetic Damage in Rodents after Short-Term Inhalation of Benzene. Environ. Mutagen. 8:29-40.	Multiple studies; Study reported lowest concentration of benzene (1 ppm for SCE and 3 ppm for micronuclei formation) to induce genotoxicity.

REPRODUCTIVE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LOAEL**	**Reference**	**Comments**
C1-C4 (Isobutane has lowest LOAEL for this group of consituents)	75-28-5	Inhalation	Rat	9000 ppm	HLS (Huntinton Life Sciences), 2008. Isobutane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4244.	Post-implantation loss observed
C5-C6	Several; see gasoline blending streams Category Analysis Document, 2008	Inhalation	Rat	NOAEL $\geq$ 6521 ppm (highest dose tested)	API (American Petroleum Institute) 2008c Baseline Gasoline Vapor Condensate, A 2-Generation Whole Body Inhalation Reproductive Study in Rats. HLS Study No. 00-4207. Huntingdon Life Sciences Laboratories, East Millstone, NJ.	
Nitrogen	7727-37-9	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.

REPRODUCTIVE TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LOAEL**	**Reference**	**Comments**
Hydrogen	1333-74-0	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
Carbon Dioxide	124-38-9	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
1,3-Butadiene	106-99-0	Inhalation	Rat	NOAEL $\geq$ 6000 ppm) (highest dose tested)	WIL Research Laboratories. 2003. An inhalation reproduction/developmental toxicity screening study of 1,3-butadiene in rats (unpublished report). (WIL-186024). WIL Research Laboratories, Inc., Ashland, OH, USA.	
Benzene	71-43-2	Inhalation	Mice	300ppm/ 13 wk	Ward, CO, Kuna, RA, Snyder, NK Alsaker, RD, Coate, WB, and PH Craig. 1985. Subchronic inhalation toxicity of benzene in rats and mice. Americ. Journ. of Industrial Medicine 7: 457-473.	Reproductive organ and sperm effects.

DEVELOPMENTAL TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LOAEL**	**Reference**	**Comments**
C1-C4 (2-butene has lowest NOAEL for this group of consituents)	107-07-7	Inhalation	Rat	NOAEL ≥ 5000 ppm (highest dose tested)	Waalkens-Brendsen, DHand JHE Arts.1992. Combined short term inhalation and reproductive/developmental toxicity screening test with butene-2 in rats. Proj. #B91-8336 (Study #1410) [2-butene].	
C5-C6	Several; see gasoline blending streams Category Analysis Document, 2008	Inhalation	Rat	463 ppm	API (American Petroleum Institute) 2009. Baseline Gasoline Vapor Condensate. Whole-Body Inhalation Developmental Toxicity Study in Mice with Baseline Gasoline Vapor Condensate. EMBSL #MRD-00-695:169534M. ExxonMobil Biomedical Sciences Inc., Annandale, NJ.	Rat study with same test material, protocol and doses was negative.
Nitrogen	7727-37-9	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.

DEVELOPMENTAL TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LOAEL**	**Reference**	**Comments**
Hydrogen	1333-74-0	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
Carbon Dioxide	124-38-9	No specific data; considered a simple asphyxiant			McManus, N. 1999. *Safety and Health in Confined Spaces*. Lewis Publishers, Boca Raton, FL. NIOSH. 1980 U.s. National Institute for Occupational Safety and Health: Working in Confined Spaces. DHHS (NIOSH) Pub. No. 80-106. NIOSH, Cincinnati, OH. NIOSH. 1987 U.s. National Institute for Occupational Safety and Health: NIOSH Respirator Decision Logis. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH.	Standard secondary source information.
1,3-Butadiene	106-99-0	Inhalation	Rat	NOAEL≥1000 ppm (highest dose tested)	Morrissey, R, Schwetz, B, Hackett, P, Sikov, M, Hardin, B, McClanahan, B, Decker, J and T Mast. 1990. Overview of reproductive and developmental toxicity studies of 1,3-butadiene in rodents. Environ. Health Perspect. **86**, 79-84.	OECD 414 Study

DEVELOPMENTAL TOXICITY						
Component	**CAS No.**	**Route**	**Species**	**LOAEL**	**Reference**	**Comments**
Benzene	71-43-2	Inhalation	Mice	20ppm	Keller, KA, and CA Snyder. 1986. Mice exposed in utero to low concentrations of benzene exhibit enduring changes in their colony forming hematopoietic cells. Toxicology 42: 171-181. Keller, KA and CA Snyder. 1988. Mice exposed in utero to 20 ppm benzene exhibit altered numbers of recognizable hematopoietic cells up to seven weeks after exposure. Fundam. Appl. Toxicol. 10: 224-232.	Hematological effect in neonates and 6 week old offspring.

Appendix 4

Literature Evaluated for Selection of C1-C4 Key Studies[13]

ACUTE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Acute Inhalation/LC50 (simple asphyxiant)	Methane	74-82-8	ACGIH Documentation of. TLV's on simple asphyxiants		Standard secondary source info
Acute Aquatic LC50 and EC50				ECOSAR model in EPI-Suite™ (EPA, 2000)	
Acute Inhalation/LC50 (simple asphyxiant)	Ethane	74-84-0	ACGIH Documentation of. TLV's on simple asphyxiants		Standard secondary source info
Acute Aquatic LC50 and EC50				ECOSAR model in EPI-Suite™ (EPA, 2000)	
Acute Inhalation/LC50 (rat, >800,000 ppm,15 min)	n-Propane	74-98-6	API HPV Robust Summary & Test Plan – Petroleum Gases	Clark, DG and D.J Tinson. 1982. acute inhalation toxicity of some halogenated and non-halogenated hydrocarbons. Human Toxicol. Vol. 1, pp 239-247.	KS=2
Acute Aquatic LC50 and EC50				ECOSAR model in EPI-Suite™ (EPA, 2000)	
Acute Inhalation/LC50 (rat, 276,000 ppm, 4 hr)	n-Butane	106-97-8	API HPV Robust Summary & Test Plan – Petroleum	Shugaev, BB. 1969. Concentrations of	Not considered valid in HPV plan, but used in

[13] Highlighted text indicates key study selected.

ACUTE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
			Gases	hydrocarbons in tissues as a measure of toxicity. Arch. Environ. Health 18:878882.	other SIDS document.
Acute Aquatic LC50 and EC50				ECOSAR model in EPI-Suite™ (EPA, 2000)	
Acute Inhalation/LC50 (rat, 520,400 ppm, 2 hr)	Isobutane	75-28-5	API HPV Robust Summary & Test Plan – Petroleum Gases	Aviado, DM, Zakhari, S and Wanatabe, T. 1977. Isobutane, Chapter 6 pp 61-72 in Non-Fluorinated propellants and solvents for aerosols. CRC Press, Cleveland, Ohio.	KS=2
Acute Aquatic LC50 and EC50				ECOSAR model in EPI-Suite™ (EPA, 2000)	
Acute Inhalation/LC50 (simple asphyxiant)	LPG	Mixture; mostly propane	ACGIH Documentation of. TLV's on simple asphyxiants		Standard secondary source info
Acute Inhalation/LC50 (rat, >950,000 ppm, 4 hr)	Ethylene	74-85-1	SIAR, Ethylene	Flury, F. 1928. Arch Exp Pathol Pharmacol.138:65.	
Acute Inhalation/LC50 (rat, >65,000 ppm, 4 hr)	Propylene	115-07-1	SIAP, Propylene/ Robust Summaries for Propylene Category, ACC Olefins Panel.	Conolly R and T Osimitz. 1981. Biochemical aspects of propylene hepatotoxicity. Toxicologist l, 112 (Abstract 406).	Low order of toxicity-narcosis induced in humans at 46,000 ppm and lower flammability limit is 20,000 ppm.
Acute Inhalation/LC50	2-Butene	107-07-7	SIAP, Butenes/ Robust	Arts, JHE. 1992. Acute	OECD limit test

ACUTE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
(rat, LC50 >10,000 ppm, 4 hr)			Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	(4-hour) inhalation toxicity study of butene-2 in rats. Report No. V92.183/352130. TNO Nutrition and Food Research, Zeist, The Netherlands. [2butene]	
Acute Inhalation/LC50 (rat, 270,000 ppm, 4 hr)	Isobutylene	115-11-7	SIAR, Isobutylene/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Shugaev, BB. 1969. Concentrations of hydrocarbons in tissues as a measure of toxicity. Arch. Environ. Health 18:878882.	Low order of toxicity – nacrosis induced in humans at >18,000 ppm, the LEL.
Acute Inhalation/LC50 (rat, >900,000 ppm, 2 hr); Considered a simple asphyxiant	Acetylene	74-86-2	HPV Test Plan – Acetylene, ACC , 2005	Riggs LK. 1925. The physiologic properties of some unsaturated hydrocarbons. Proc Soc Exp Biol Med 22: 269-270	LC50 in humans determined to be >100,000 ppm, which was considered critical SIDS study in test plan.

REPEAT DOSE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Repeated Dose (simple asphyxiant)	Methane	74-82-8	ACGIH Documentation of TLVs		Standard secondary information
Repeated Dose Inhalation/ 28 day (NOAEL ≥16,000 ppm)	Ethane	74-84-0	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. Ethane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4243.	KS=1; OECD 422
Repeated Dose Inhalation/ 28 day (Rat, NOAEL ≥4,000 ppm)	n-Propane	74-98-6	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. n-Propane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4245.	KS=1; OECD 422

REPEAT DOSE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Repeated Dose Inhalation/ 28 day (Rat, NOAEL ≥9,000 ppm)	n-Butane	106-97-8	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. n-Butane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4242.	KS=1; OECD 422
Repeated Dose Inhalation/ 28 day (Rat, NOAEL ≥9,000 ppm)	Isobutane	75-28-5	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. Isobutane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4244.	KS=1; OECD 422
Repeated Dose Inhalation/ 13 wk (Rat, NOAEL ≥10,000 ppm)	LPG	Mixture; mostly propane		HLS (Huntinton Life Sciences), 2008. LPG: 13-Week whole body inhalation toxicity study in rats with neurotoxicity assessments and *in vivo* genotoxicity assessments. Conducted for the American Petroleum Insitute. Draft report 03-6141.	KS=1; OECD 413/474

REPEAT DOSE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Repeated Dose Inhalation/ 90 day (NOAEL ≥ 10,000 ppm)	Ethylene	74-85-1	SIAR, Ethylene	Chemical Industry Institute of Toxicology, Research Triangle Park, North Carolina, USA. CIIT summary report, a ninety day inhalation toxicology study in albino rats exposed to atmospheric ethylene gas. 1977.	
Repeated Dose Inhalation/ 103 wk (rat, NOAEL ≥ 5,000 ppm)	Propylene	115-07-1	SIAP, Propylene; Robust Summaries for Propylene Streams, ACC	National Toxicology Program. 1985. Toxicology and carcinogenesis studies of propylene (CAS No. 115-07-1) in F344/N rats and B6C3F1 mice (inhalation studies). Report NTP TR 272, National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health. Research Triangle Park, NC, USA.	Inflammation of nasal cavity seen at 5000 ppm, but study considered negative.
Repeated Dose Inhalation/ 39-46 d (rat, LOAEL== 5,000 ppm; NOAEL = 2500 ppm)	2-Butene	107-07-7	SIAP, Butenes/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Waalkens-Brendsen, DH and JHE Arts. 1992. Combined short term inhalation and reproductive/developmental toxicity screening test with Butene-2 in rats. Proj. #B91-8336 (Study #1410) [2-butene]	KS=1. Body weight reduced. Repeat dose NOAEL for 1-butene = 8000 ppm.

REPEAT DOSE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Repeated Dose Inhalation/ 105 wk (rat, LOAEL=8,000; NOAEL = 2000 ppm)	Isobutylene	115-11-7	SIAR, Isobutylene/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	National Toxicology Program (NTP). 1998. Toxicology and carcinogenesis studies of isobutene (CAS No. 115-11-7) in F344/N Rats and B6C3F1 Mice (inhalation studies). Report NTP TR 487, National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health. Research Triangle Park, NC, USA.	Considered a critical SIDS endpoint study in OECD document
Repeated Dose Inhalation/ 6 mo (rat & dog , LOAEL≤28,700 ppm)	Acetylene	74-86-2	HPV Test Plan – Acetylene, ACC , 2005	Horn HJ, Weir RJ Jr and Reese WH. 1957. Inhalation toxicology of methylacetylene. Arch Ind Health 15: 20-26.	KS=2. Analog methyl-acetylene study. Only one concentration studied, but was considered to be valid with restrictions

IN VITRO GENETIC TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Genetic Tox – *In Vitro* Nonmammalian system – *salmonella typhimurium* (negative)	Methane	74-82-8		National Toxicology Program (NTP). 1993. Salmonella test on methane. NTP Report 297396. National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health. Research Triangle Park, NC, USA.	
No data	Ethane	74-84-0			
Genetic Tox – *In Vitro* Nonmammalian system – *salmonella typhimurium* (negative)	n-Propane	74-98-6	API HPV Robust Summary & Test Plan – Petroleum Gases	Kirwin, CJ and Thomas, WC. 1980. In vitro microbio-logical mutagenicity studies of hydro-carbon propellants. J. Soc. Cosmet. Chem. Vol. 31.) pp 367-370	KS=2
Genetic Tox – *In Vitro* Nonmammalian system – *salmonella typhimurium* (negative)	n-Butane	106-97-8	API HPV Robust Summary & Test Plan – Petroleum Gases	Kirwin, CJ and Thomas, WC. 1980. In vitro microbio-logical mutagenicity studies of hydro-carbon propellants. J. Soc. Cosmet. Chem. Vol. 31.) pp 367-370	KS=2
Genetic Tox – *In Vitro* Nonmammalian system – *salmonella typhimurium* (negative)	Isobutane	75-28-5	API HPV Robust Summary & Test Plan – Petroleum Gases	Kirwin, CJ and Thomas, WC. 1980. In vitro microbio-logical mutagenicity studies of hydro-carbon propellants. J. Soc. Cosmet. Chem. Vol. 31.) pp 367-370	KS=2

IN VITRO GENETIC TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
No data	LPG	Mixture; mostly propane			
Genetic Tox – *In Vitro* Nonmammalian system – *salmonella typhimurium* (negative) Genetic Tox – *In Vitro* Mammalian system – CHO chromosomal aberrations (negative)	Ethylene	74-85-1	SIAR, Ethylene	Hamm TE jr, Guest D, Dent JG. Chronic toxicity and oncogenicity bioassay of inhaled ethylene in Fisher-344 rats. Fundamental and Appl Toxicol. 1984;4:473-8. Riley S. Ethylene: Induction of chromosome aberrations in cultured chinese hamster ovary (CHO) cells. Corning Hazleton Report No. 1458/1-1052, April 1996.	
Genetic Tox – *In Vitro* Nonmammalian system – *salmonella typhimurium* (negative) Genetic Tox – *In Vitro* Mammalian system – mouse lymphoma (negative)	Propylene	115-07-1	SIAP, Propylene	Inveresk. 2003. Ames test draft report. Inveresk Research. McGregor, D, Brown, AG, Cattanack, P, Edwards, I, McBride, D, Riach, C, Shepherd, W and WJ Caspary. 1991. Responses of the L5178Y mouse lymphoma forward mutation assay: V. Gases and vapors. Environ. Mol. Mutag., 17:122-129.	Positive in single bacterial strain in Ames assay in presence of s9, but negative in other strains.

IN VITRO GENETIC TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Genetic Tox – *In Vitro* Nonmammalian system – *salmonella typhimurium* (negative) Genetic Tox – *In Vitro* Mammalian system – rat lymphocyte clastogenicity (negative)	2-Butene	107-07-7	SIAP, Butenes/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Thompson, PW. 1992. Butene-2: Reverse mutation assay "Ames test" using *Salmonella typhimurium*. Proj. #44/812. SafePharm Laboratories, UK, Derby UK. [2-butene] Wright, NP. 1992. Butene-2: Metaphase analysis in rat lymphocytes *in vitro*. Proj. #44/813. SafePharm Laboratories, UK, Derby UK. [2-butene]	1-butene and isobutylene also negative. Isobutylene also negative

IN VITRO GENETIC TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Genetic Tox – *In Vitro* Nonmammalian system – *salmonella typhimurium* (negative) Mammalian system – mouse embryo fibroblast transformations; mouse lymphoma (negative)	Isobutylene	115-11-7	SIAR, Isobutylene/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	McGregor, DB, Reach, CG. 1981. Isobutylene: Ames test for mutagenic activity with salmonella TA 1535, TA100, TA1537, TA1538, TA98, and e.coli WP2 uvrB) pKM101), unpublished rpt# 2098, IRI Proj. 704338 Inveresk Research Institute, for Essochem Europe, Inc. Machelen, Belgium McGregor, DB, Poole, A. 1981. Isobutylene: induction of morphological transformation in C3H/10T½ clone 8 cells. Inveresk Research International, Musselburgh, Scotland for Essochem Europe, Inc., Machelen, Belgium McGregor, D.B., Ross, C.A. 1981. Isobutylene: assessment of mutagenic potential in the mouse lymphoma mutation assay. Inveresk Research International, Musselburgh, Scotland for Essochem Europe Inc., Machelen, Belgium.	

***IN VITRO* GENETIC TOXICITY**					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Genetic Tox – *In Vitro* Nonmammalian system – *salmonella typhimurium* (negative)	Acetylene	74-86-2	HPV Test Plan – Acetylene, ACC, 2005	Hughes TJ, Sparacino, C and S Frazier. 1984. Validation of chemical and biological techniques for evaluation of vapors in ambient air/mutagenicity testing of twelve (12) vapor-phase compounds. EPA Report Number 68-02-3170, NTIS Publication PB84-164219.	Also applies to methacetylene; methacetylene was positive in *e.coli* assay, but general weight of evidence for acetylene judged to be negative

IN VIVO GENETIC TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
No data	Methane	74-82-8			
No data	Ethane	74-84-0			
No data	n-Propane	74-98-6			
No data	n-Butane	106-97-8			
No data	Isobutane	75-28-5			
Genetic Tox – *In Vivo* Micronuclei formation (negative)	LPG	Mixture; mostly propane		HLS (Huntinton Life Sciences), 2008. LPG: 13-Week whole body inhalation toxicity study in rats with neurotoxicity assessments and *in vivo* genotoxicity assessments. Conducted for the American Petroleum Insitute. Draft report 03-6141.	KS=1; Rat; OECD 413/474
Genetic Tox – *In Vivo* Bone marrow /blood micronuclei formation (negative)	Ethylene	74-85-1	SIAR, Ethylene	Vergenes, JS and IM Pritts. 1994. Effects of ethylene on micronucleus formation in the bone marrow of rats and mice following four weeks of inhalation exposure. Mutat Res.324: 87-91.	Mouse, inhalation, 3,000 ppm maximum concentration tested
Bone marrow /blood micronuclei formation (negative)	Propylene	115-07-1	SIAP, Propylene	DuPont (2002). Propylene biomarker/mutagenicity dose-response study in rats. Rat bone marrow micro-nucleus assay by inhalation. DuPont Haskell Laboratory. Report No. DuPont-9106.	Mouse, inhalation, 10,000 ppm maximum concentration tested

IN VIVO GENETIC TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Bone marrow /blood micronuclei formation (negative)	1-Butene	106-98-9	SIAP, Butenes/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Khan, SH, and CO Ward. 1985. Micronucleus test of Gulftene® 4. Unpublished report # 84-2113 by Gulf Life Sciences Center for Gulf Oil Chemicals Co. [1-butene]	Mouse, inhalation, 22,000 ppm maximum concentration tested; 1-butene; also see isobutylene results
Bone marrow /blood micronuclei formation (negative)	Isobutylene	115-11-7	SIAR, Isobutylene/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Przygoda, R. 1990. *In vivo* mammalian bone marrow micronucleus assay for isobutylene. Project #236030. Exxon Biomedical Sciences Inc. East Millstone, NJ	Mouse, inhalation, 10,000 ppm maximum concentration tested
Genetox in vivo (to be determined)	Acetylene	74-86-2	HPV Test Plan – Acetylene, ACC , 2005	To be determined per test plan.	

REPRODUCTIVE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
No data	Methane	74-82-8			
Reproductive Tox Inhalation (Rat, NOAEL ≥16,000 ppm)	Ethane	74-84-0	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. Ethane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4243.	KS=1; OECD 422
Reproductive Tox Inhalation (Rat, NOAEL ≥12,000 ppm)	n-Propane	74-98-6	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. n-Propane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4245.	KS=1; OECD 422
Reproductive Tox Inhalation (Rat, NOAEL ≥9,000 ppm)	n-Butane	106-97-8	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. n-Butane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4242.	KS=1; OECD 422

REPRODUCTIVE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Reproductive Tox Inhalation (Rat, LOAEL =9,000 ppm; NOAEL = 3,000)	Isobutane	75-28-5	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. Isobutane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4244.	KS=1; OECD 422; Post-implantation loss observed
Reproductive Tox Inhalation (Rat, NOAEL ≥10,000 ppm)	LPG	Mixture; mostly propane	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. LPG: 13-Week whole body inhalation toxicity study in rats with neurotoxicity assessments and *in vivo* genotoxicity assessments. Conducted for the American Petroleum Insitute. Draft report 03-6141.	KS=1 (OECD 413/474 study) Sperm morphology study also included in protocol
Reproductive Tox Inhalation (Rat, NOAEL ≥5,000 ppm)	Ethylene	74-85-1	SIAR, Ethylene	Aveyard L. 1996. Ethylene: Inhalation (Head-only) Reproduction/Development Toxicity Study in the Rat. Corning Hazleton Report No. 1458/2-1050.	

REPRODUCTIVE TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
No data	Propylene	115-07-1			No effects observed on reproductive organs in two species during NTP repeat dose studies of 14 or 103 wk.
Reproductive Tox Inhalation (Rat, NOAEL ≥5,000 ppm)	2-butene	107-07-7	SIAP, Butenes/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Waalkens-Brendsen, DH and JHE Arts. 1992. Combined short term inhalation and reproductive/developmental toxicity screening test with Butene-2 in rats. Proj. #B91-8336 (Study #1410) [2-butene]	
No data	Isobutylene	115-11-7			No effects observed on reproductive organs in two species during repeat dose study.
No data – see comments	Acetylene	74-86-2	HPV Test Plan – Acetylene, ACC , 2005		HPV Test Plan indicates that reproductive and developmental toxicity of acetylene is unlikely, therefore no testing has been scheduled.

DEVELOPMENTAL TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
No data	Methane	74-82-8			
Developmental Tox Inhalation (Rat, NOAEL ≥16,000 ppm)	Ethane	74-84-0	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. Ethane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4243.	KS=1; OECD 422
Developmental Tox Inhalation (Rat, NOAEL ≥12,000 ppm)	n-Propane	74-98-6	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. n-Propane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4245.	KS=1; OECD 422
Developmental Tox Inhalation (Rat, NOAEL ≥9,000 ppm)	n-Butane	106-97-8	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. n-Butane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4242.	KS=1; OECD 422

DEVELOPMENTAL TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Developmental Tox Inhalation (Rat, NOAEL ≥9,000 ppm)	Isobutane	75-28-5	API HPV Robust Summary & Test Plan – Petroleum Gases	HLS (Huntinton Life Sciences), 2008. Isobutane: Combined repeated exposure toxicity, reproduction and neurotoxicity screening in rats via whole-body inhalation exposures. Conducted for the American Petroleum Insitute. Draft report 03-4244.	KS=1; OECD 422;
Developmental Tox Inhalation (Rat, NOAEL ≥10,000 ppm)	LPG	Mixture; mostly propane		HLS (Huntinton Life Sciences), 2008. LPG: Embryo-fetal toxicity study in rats by inhalation exposure.. Conducted for the American Petroleum Insitute. Draft report 03-42-53.	KS=1 (OECD 414)
Developmental Tox Inhalation (Rat, NOAEL ≥10,000 ppm)	Ethylene	74-85-1	SIAR, Ethylene	Aveyard L. 1996. Ethylene: Inhalation (Head-only) Reproduction/Development Toxicity Study in the Rat. Corning Hazleton Report No. 1458/2-1050.	
Developmental Tox Inhalation (Rat, NOAEL ≥10,000 ppm)	Propylene	115-07-1	SIAP, Propylene	BASF Aktiengesellschaft 2002. Propylene - Prenatal developmental inhalation toxicity study in Wistar rats; vapor exposure. Experimental Toxicology and Ecology Laboratory, Rhein, Germany. Project #31R0416/01019.	

DEVELOPMENTAL TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Developmental Tox Inhalation (Rat, NOAEL ≥5000 ppm)	2-Butene	107-07-7	SIAP, Butenes/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Waalkens-Brendsen, DH and JHE Arts. 1992. Combined short term inhalation and reproductive/developmental toxicity screening test with Butene-2 in rats. Proj. #B91-8336 (Study #1410) [2-butene]	
Developmental Tox Inhalation (Rat, NOAEL ≥8000 ppm)	Isobutylene	115-11-7	SIAR, Isobutylene/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Central Toxicology Laboratory (CTL). 2002. Isobutylene: Prenatal Developmental Toxicity Study in the Rat. CTL/RR0907/Regulatory Report. Cheshire, UK.	
No data – see comments	Acetylene	74-86-2	HPV Test Plan – Acetylene, ACC , 2005		HPV Test Plan indicates that repro dev tox of acetylene is unlikely, therefore no testing has been scheduled.

DEVELOPMENTAL TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
No data	Methane	74-82-8			
Developmental Tox Inhalation (Rat, LOAEL >16,000 ppm; NOAEL = 16, 000 ppm)	Ethane	74-84-0		API HPV study- draft report (OECD 422)	KS=1
Developmental Tox Inhalation (Rat, LOAEL >12,000 ppm; NOAEL = 12, 000 ppm)	n-Propane	74-98-6		API HPV study- draft report (OECD 422)	KS=1
Developmental Tox Inhalation (Rat, LOAEL >9,000 ppm; NOAEL = 9,000 ppm)	n-Butane	106-97-8		API HPV study- draft report (OECD 422)	KS=1
Developmental Tox Inhalation (Rat, LOAEL >9,000 ppm; NOAEL = 3,000 ppm)	Isobutane	75-28-5		API HPV study- draft report (OECD 422)	KS=1; Post-implantation loss observed
Developmental Tox Inhalation (Rat, LOAEL >10,000 ppm; NOAEL = 10, 000 ppm)	LPG	Mixture; mostly propane		API HPV study- draft report (OECD 414)	
Developmental Tox Inhalation (Rat, LOAEL >5,000 ppm; NOAEL = 5,000 ppm)	Ethylene	74-85-1	SIAR, Ethylene	Aveyard L. Ethylene: Inhalation (Head-only) Reproduction/Development Toxicity Study in the Rat. Corning Hazleton Report No. 1458/2-1050, April 1996.	
Developmental Tox Inhalation (Rat, LOAEL >10,000 ppm; NOAEL = 10,000 ppm)	Propylene	115-07-1	SIAP, Propylene	BASF Aktiengesellschaft (2002). Propylene - Prenatal developmental inhalation toxicity study in Wistar rats; vapor exposure. Experimental Toxicology and Ecology Laboratory, Rhein, Germany. Project #31R0416/01019.	

DEVELOPMENTAL TOXICITY					
Endpoint	**Component**	**CAS No.**	**Secondary Source**	**Primary Source**	**Comment**
Developmental Tox Inhalation (rat, LOAEL >8,000 ppm for 1-butene and >5000 ppm for 2-butene; NOAELs = 8,000 ppm and 5,000 ppm, respectively)	Butylene	25167-67-3 (mixed isomers)	SIAP, Butenes/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Waalkens-Brendsen, D.H. and Arts, J.H.E. 1992. Combined short term inhalation and reproductive/developmental toxicity screening test with Butene-2 in rats. Proj. #B91-8336 (Study #1410) [2-butene]	
Developmental Tox Inhalation (Rat, LOAEL >8,000 ppm; NOAEL = 8,000 ppm)	Isobutylene	115-11-7	SIAR, Isobutylene/ Robust Summaries for Low 1,3-Butadiene C4 Category, ACC Olefins panel.	Central Toxicology Laboratory (CTL) (2002). Isobutylene: Prenatal Developmental Toxicity Study in the Rat. CTL/RR0907/Regulatory Report. Cheshire, UK.	
No data – see comments	Acetylene	74-86-2	HPV Test Plan – Acetylene, ACC , 2005		HPV Test Plan indicates that repro dev tox of acetylene is unlikely, therefore no testing has been scheduled.