HIGH PRODUCTION VOLUME (HPV)

CHEMICAL CHALLENGE PROGRAM

-

TEST PLAN

For

C3-5 BUTENE-ISOBUTYLENE-RICH

CAS #102479-87-8

Prepared by:

ExxonMobil Chemical Company

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EXECUTIVE SUMMARY

Under the Environmental Protection Agency (EPA) High Production Volume (HPV) Chemical Challenge Program (Program), ExxonMobil Chemical Company has committed to voluntarily compile a Screening Information Data Set (SIDS) for C3-5 Butene-Isobutylene-Rich (C3-5 BIR), CAS #102479-87-8.

Existing data and technical analyses adequately characterize the SIDS endpoints for C3-5 BIR and support a screening-level hazard assessment, which informs the public about the SIDS-based hazards of this substance. Sufficient data and information exist to characterize all endpoints in the HPV Program. Therefore, no additional testing is proposed.

The C3-5 BIR stream is a complex substance that contains a predominant ether fraction in combination with a smaller hydrocarbon fraction. A search for existing studies/information and their review identified adequate data for select constituents to characterize all SIDS endpoints for the stream. Data suggest that the C3-5 BIR stream generally presents a low order of hazard for human health and low to moderate order of environmental hazard for the predominant groups of constituents as a whole. The predominant constituents of the stream are relatively volatile. Information on their fate in the environment suggests that once in the atmosphere, they will be largely degraded through physical processes at a relatively rapid rate.

TABLE OF CONTENTS
TEST PLAN FOR C3-5 BUTENE-ISOBUTYLENE-RICH

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CAS No. 102479-87-8

I. INTRODUCTION

Under the U.S. Environmental Protection Agency (EPA) High Production Volume (HPV) Chemical Challenge Program (Program), ExxonMobil Chemical Company committed to voluntarily compile a Screening Information Data Set (SIDS) that can be used for an initial hazard assessment of the C3-5 Butene-Isobutylene Rich (C3-5 BIR) stream, CAS No. 102479-87-8. Although there are no data for the stream, based on its composition, it was determined that data for three constituents can be used to characterize the SIDS endpoints because they comprise a large fraction of the stream and therefore, will define the fate and effects of the stream. The three substances are methyl-tert-butyl ether (CAS No. 1634-04-4), tert-amyl-methyl ether (CAS No. 994-05-8), and methyl-sec-butyl ether (CAS No. 994-05-8).

This assessment includes data for selected physicochemical, environmental fate, and mammalian and environmental effect endpoints identified by the U.S. HPV Program. Procedures to assess the reliability of selected data for inclusion in this test plan were based on guidelines described by Klimisch *et al*. (1997) and identified within the U.S. EPA (1999) document titled *Determining the Adequacy of Existing Data*. The following sections describe the C3-5 BIR stream and its manufacturing process, and data used to characterize the various endpoints in the HPV Program. After a review of the existing data, ExxonMobil Chemical Company believes that data needed to adequately assess all SIDS endpoints have been identified and that additional testing is not necessary.

II. CHEMICAL DESCRIPTION, MANUFACTURING PROCESS, AND USE

The C3-5 BIR stream is composed of several constituent substances (Table 1). The predominant chemical fraction in this stream is methyl-tertiary-butyl ether (also referred to as MTBE) which can comprise from approximately 65% of the stream. A second chemical fraction, which can also comprise a large proportion of the stream is 2-methoxy-2-methylbutane, which is also referred to as tert-amyl methyl ether (TAME). This fraction comprises approximately 28% of the stream. A third fraction, which can also comprise a significant portion of the stream, is methyl-sec-butyl ether (also referred to as MSBE), and can be as much as 4%. Together these three fractions can comprise up to 97% of the stream. All other groups or identified chemicals in Table 1 each comprise less than 5% of the stream.

In the chemical plant, a mostly C5 stream is brought into the isoamylene unit (IAU) from upstream fractionation. To remove the isoamylene (2-methyl-butene-1 and 2-methyl-butene-2), the stream is run across a catalyst that oxygenates the isoamylene into TAME (tertiary-amyl methyl ether) using methanol. This TAME is then fractionated away from the remaining C5 stream, and decomposed back to isoamylene and methanol and recovered as product. In the decomposition reaction, there are side-reactions that occur that cause generation of undesirable components. These are fractionated off as the IAU light co-product (C3-5 BIR stream) and are returned to the refinery for further processing and use in gasoline blending.

Table 1. Percent composition ranges of predominant constituents in the C3-5 Butene-Isobutylene Rich stream.

C3-5 BUTENE-ISOBUTYLENE RICH STREAM		
Component	**cas no.**	**Percent Composition Range**
MTBE (Methyl-Tert-Butyl Ether)	1634-04-4	64.8
TAME (tert-amyl methyl ether) (2-methoxy-2-methylbutane)	994-05-8	28.3
MSBE (Methyl-Sec-Butyl Ether)	6795-87-5	3.6
TBA (tert-butyl alcohol)	75-65-0	0.4
Other Voc		2.8

III. TEST PLAN RATIONALE AND DATA SUMMARY

The predominant constituent chemical group of the C3-5 Butene-Isobutylene Rich stream is the methoxypentanes (3 constituents), at as much as 97% of the stream, will be responsible for the biological effects exhibited by the stream as a whole. The few remaining chemical groups or individual chemical constituents, that are present at levels between 0.4% and 3%, will not contribute to a greater adverse biological effect than that resulting from the major group. Therefore, data from representative constituents from this group will be used to characterize the overall biological and fate characteristics of the stream.

The basic strategy of this test plan for characterizing the human health hazards of the C3-5 Butene-Isobutylene Rich stream is to evaluate data for the major components of the stream. The major chemical components of the stream in the C3-5 Butene-Isobutylene Rich stream have been tested for human health toxicity endpoints. Available data on these components prove to provide sufficient information to develop scientific judgment-based characterizations of the human health effects of the stream for purposes of satisfying HPV program requirements. Therefore, no additional human health toxicity testing is proposed. The hazard characterization for the C3-5 Butene-Isobutylene Rich stream will include the hazards of methyl-tert-butyl ether (MTBE), tert-amyl-methyl ether (TAME), and methyl-sec-butyl ether (MSBE).

The environmental fate and effects of the methoxypentanes (ethers) will be characterized by 2-methoxy-2-methylpropane, also referred to as methyl-tert-butyl ether (MTBE), and 2-methoxy-2-methylbutane, also referred to as tert-amyl methyl ether (TAME), which have SIDS datasets. Use of the MTBE and TAME data to characterize the ether group in this stream is supported by calculated results from the ECOSAR computer model (ECOSAR, 2004) using EPI Suite™ (2000) modeled input data. The 48- or 96-hour data for each of the freshwater fish, daphnid, and green alga endpoints show that the three ethers are expected to cause similar effects. The environmental

fate and effects of the remaining constituents will not be characterized as they do not occur in sufficient quantity to impart an effect.

All MTBE and TAME test data identified within this document were developed using the parent substance. Additional data for this group used to characterize the aquatic toxicity endpoints were developed using the ECOSAR computer model (ECOSAR, 2004) provided within EPI Suite™ (2000). This model applies an equation for neutral organics to estimate aquatic toxicity and is therefore considered appropriate to estimate aquatic toxicity for the representative substances.

Data used to characterize the various physicochemical, environmental fate, and environmental and mammalian health endpoints are described below.

A. Physicochemical Data

Calculated and measured MTBE, TAME, and MSBE physicochemical data from the literature are listed in Table 2.

Table 2. Selected physico-chemical properties for three select constituents used to characterize the C3-5 Butene-Isobutylene Rich- stream.

ENDPOINT	MTBE	TAME	MSBE
Melting Point (ºC)	-108.6 (Lide *et al.*, 1998-1999)	-81.2 (U.S. EPA, 2000)	-100 (U.S. EPA, 2000)
Boiling Point (ºC at 1012 hPa)	55.2 (Lide *et al.*, 1998-1999)	86.3 (Lide *et al.*, 1998-1999)	65 (U.S. EPA, 2000)
Density (g/cm^3 at 20°C)	0.740 (Lide *et al.*, 1998-1999)	0.770 (Lide *et al.*, 1998-1999)	0.742 (Aldrich Handbook, 2003-2004)
Vapor Pressure (Pa at 25°C)	33,330 (Daubert & Danner, 1995)	12,000 (Huttunen *et al.*, 1997)	27,730 (Daubert & Danner, 1989)
Water Solubility (mg/l at 25°C)	51,000 (Bennett & Philip, 1928)	5,468 (U.S. EPA, 2000)	16,400 (Wakita, *et. al*., 1986)
Log K_{ow} (at 25°C)	0.94 (Hansch *et al.*, 1995)	1.55 (Huttunen *et al.*, 1997)	1.47 (U.S. EPA, 2000)

MTBE - methyl-tert-butyl ether
TAME - tert-amyl methyl ether
MSBE - methyl-sec-butyl ether

Conclusion

Based on data identified for MTBE, TAME, and MSBE, the C3-5 BIR stream will exhibit a melting range between approximately -81 to -109°C, a boiling range between approximately 55 to 87°C, a density ranging from approximately 0.74 to 0.77 g/cm^3 at 20°C, and a vapor pressure between approximately 12,000 to 33,330 Pa at 25°C. The predominant constituents of the C3-5 BIR stream have water solubilities that range from 5,468 to 51,000 mg/l at 25°C and Log K_{ow} values that range from approximately 0.94 to 1.55.

B. Environmental Fate Data

Biodegradation

Biodegradation of an organic substance by bacteria can provide energy and carbon for microbial growth. This process results in a structural change of an organic substance and can lead to the complete degradation of that substance, producing carbon dioxide and water.

The test guideline used to assess the biodegradability of MTBE was OECD 301D, Closed Bottle Biodegradation Test. This test design uses a sealed bottle, which is appropriate considering the test material is relatively volatile. The source of the microbial inoculum used in this study was a domestic wastewater treatment facility and it was not acclimated. MTBE exhibited 0% biodegradation after 28 days (Huels AG, 1991a).

The biodegradability of TAME was also assessed following the OECD 301D, Closed Bottle Biodegradation Test Guideline. The source of the microbial inoculum used in this study was a domestic wastewater treatment facility and it was not acclimated. TAME exhibited 4% biodegradation after 28 days (Bealing, 1995).

No biodegradation data is available for MSBE. QSAR modeling, using the BIOWIN models of EPISuite version 3.20, predicts that MSBE will not biodegrade fast. The modeling results are consistent with the experimental results for MTBE and TAME.

Conclusion

Based on experimental data for MTBE and TAME and modeled results for MSBE, the C3-5 BIR stream is expected to demonstrate an overall low extent of biodegradation. However, in the environment, the fate of the C3-5 BIR stream constituents have the potential to partition primarily to air because the they have relatively high vapor pressures, which suggests that they can volatilize to the air at a rapid rate if released.

Photodegradation – Photolysis

Direct photochemical degradation occurs through the absorbance of solar radiation by a chemical substance in aqueous solution. If the absorbed energy is high enough, then the resultant excited state of the chemical may undergo a transformation. 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 to 750 nm range. Light wavelengths longer than 750 nm do not contain sufficient energy to break chemical bonds, and wavelengths below 290 nm are shielded from the earth by the stratospheric

ozone layer (Harris, 1982a).

An approach to assessing the potential for a substance to undergo photochemical degradation is to assume that degradation will occur in proportion to the amount of light wavelengths >290 nm absorbed by constituent molecules (Zepp and Cline, 1977). The oxygen non-bonding electrons in ethers do not give rise to absorption above 160 nm, which is why pure ether solvents can be used in spectroscopic studies. Consequently, the ether fraction of the C3-5 BIR stream is not subject to photolytic processes in the aqueous environment.

Similarly, saturated and unsaturated hydrocarbons like those in the C3-5 BIR stream do not absorb light above 290 nm. Therefore, the hydrocarbon constituents of this stream will not exhibit photolytic degradation.

Conclusion

Based on the potential for photolysis of ethers and hydrocarbons, this process is not expected to significantly contribute to the degradation of constituents of the C3-5 BIR stream.

Photodegradation – Atmospheric Oxidation

Photodegradation can be measured (US EPA, 1999a) or estimated using an atmospheric oxidation potential (AOP) model accepted by the EPA (US EPA, 1999b). Atmospheric oxidation as a result of hydroxyl radical attack is not direct photochemical degradation, but rather indirect degradation.

The constituents of the C3-5 BIR stream have the potential to volatilize to air, based on the vapor pressure of three of the predominant constituents, where they are subject to atmospheric oxidation. In air, C3-5 BIR stream constituents can react with photosensitized oxygen in the form of hydroxyl radicals ($^{\bullet}OH$). The computer program AOPWIN (atmospheric oxidation program for Microsoft Windows) (U.S. EPA, 2000) calculates a chemical half-life for a 12-hour day (the 12-hour day half-life value normalizes degradation to a standard day light period during which hydroxyl radicals needed for degradation are generated), based on an $^{\bullet}OH$ reaction rate constant and a defined $^{\bullet}OH$ concentration.

MTBE has a calculated half-life in air of 56.9 hours or 4.7 days (12-hour day), based on a rate constant of 2.26×10^{-12} cm^3/molecule*sec and an $^{\bullet}OH$ concentration of 1.5×10^6 $^{\bullet}OH$ /cm^3. TAME has a calculated half-life in air of 24.6 hours or 2.1 days (12-hour day), based on a rate constant of 5.22×10^{-12} cm^3/molecule*sec and an $^{\bullet}OH$ concentration of 1.5×10^6 $^{\bullet}OH$ /cm^3. In comparison, MSBE has a calculated half-life in air of 7.6 hours or 0.6 days (12-hour day), based on a rate constant of 1.69×10^{-13} cm^3/molecule*sec and an $^{\bullet}OH$ concentration of 1.5×10^6 $^{\bullet}OH$ /cm^3.

Conclusion

Atmospheric oxidation via hydroxyl radical attack can be a significant route of degradation for constituents in the C3-5 BIR stream and is expected to occur at a moderate rate. Based on calculated values for three chemicals that are representative of the majority of stream constituents, C3-5 BIR stream constituents are expected to have an atmospheric half-life of approximately 5 days or less as a result of indirect photolysis by hydroxyl radical attack.

Stability in Water (Hydrolysis)

Hydrolysis of an organic chemical is the transformation process in which a water molecule or hydroxide ion reacts to form a new carbon-oxygen bond. Chemicals with leaving groups that have a potential to hydrolyze include alkyl halides, amides, carbamates, carboxylic acid esters and lactones, epoxides, phosphate esters, and sulfonic acid esters (Neely, 1985). The lack of a suitable leaving group renders a compound resistant to hydrolysis. Ether and hydrocarbon constituents of the C3-5 BIR stream are resistant to hydrolysis because they lack functional groups that are hydrolytically reactive and Harris (1982b) identifies ether groups as generally resistant to hydrolysis.

Conclusion

Hydrolysis will not contribute to the removal from the environment of constituents in the C3-5 BIR stream**.**

Chemical Distribution In The Environment (Fugacity Modeling)

Fugacity-based multimedia modeling provides basic information on the relative distribution of a chemical between selected environmental compartments (i.e., air, soil, water, sediment, suspended sediment, and biota). Two widely used fugacity models are the EQC (Equilibrium Criterion) Level I and Level III model (Mackay, 1998a; Mackay, 1998b).

The input data required to run a Level I model include basic physicochemical parameters; distribution is calculated as percent of chemical partitioned to 6 compartments (air, soil, water, suspended sediment, sediment, biota) within a unit world. Level I data are basic partitioning data that allow for comparisons between chemicals and indicate the compartment(s) to which a chemical may to partition, based on selected physical parameters. The Level III model uses the same physical parameters as the Level I model, but also requires half-life degradation data for the air, soil, water, and sediment compartments, as well as emission parameters for the air, water, and soil compartments.

Results of the Mackay Level I and Level III environmental distribution models for three representative stream constituents are shown in Tables 3 and 4, respectively.

Table 3. Environmental distribution as calculated by the Mackay (1998a) Level I fugacity model for select constituents used to characterize the C3-5 Butene-Isobutylene Rich stream.

ENVIRONMENTAL COMPARTMENT	MTBE DISTRIBUTION* (%)	TAME DISTRIBUTION** (%)	MSBE DISTRIBUTION† (%)
Air	91.95	97.77	96.70
Water	7.99	2.16	3.22
Soil	0.06	0.07	0.08
Sediment	<0.01	<0.01	<0.01
Suspended Sediment	<0.01	<0.01	<0.01
Biota	<0.01	<0.01	<0.01

* Distribution is based on the following model input parameters for MTBE (methyl-tert-butyl ether):

Molecular Weight	88.15
Temperature	25° C
Log K_{ow}	0.94
Water Solubility	51,000 g/m^3
Vapor Pressure	33,330 Pa
Melting Point	-108.6° C

** Distribution is based on the following model input parameters for TAME (tert-amyl methyl ether):

Molecular Weight	102.18
Temperature	25° C
Log K_{ow}	1.55
Water Solubility	5,468 g/m^3
Vapor Pressure	12,000 Pa
Melting Point	-81.22° C

† Distribution is based on the following model input parameters for MSBE (methyl-sec-butyl ether):

Molecular Weight	88.15
Temperature	25° C
Log K_{ow}	1.47
Water Solubility	16,400 g/m^3
Vapor Pressure	27,730 Pa
Melting Point	-100° C

Table 4. Environmental distribution as calculated by the Mackay (1998b) Level III fugacity model for select constituents used to characterize the C3-5 Butene-Isobutylene Rich stream.

ENVIRONMENTAL COMPARTMENT	MTBE DISTRIBUTION* (%)	TAME DISTRIBUTION* (%)	MSBE DISTRIBUTION† (%)
Air	21.1	26.2	7.3
Water	50.5	55.2	64.8
Soil	28.3	18.6	27.8
Sediment	0.1	0.1	0.2

* Distribution for MTBE (methyl-tert-butyl ether) is based on the following model input parameters, reaction half-life in hours as predicted using EPI SuiteTM (2000), and a model default emission rate of 1000 kg/hr into each of the air, water, and soil compartments:

Molecular Weight	88.15	Reaction half-life (hr):	
Temperature	25° C	Air (gaseous)	56.8
Log K_{ow}	0.94	Water (no susp. part.)	360
Water Solubility	51,000 g/m^3	Bulk Soil	720
Vapor Pressure	33,330 Pa	Bulk Sediment	3,240
Melting Point	-108.6° C		

** Distribution for TAME (tert-amyl methyl ether) is based on the following model input parameters, reaction half-life in hours as predicted using EPI SuiteTM (2000), and a model default emission rate of 1000 kg/hr into each of the air, water, and soil compartments:

Molecular Weight	102.18	Reaction half-life (hr):	
Temperature	25° C	Air (gaseous)	46.7
Log K_{ow}	1.55	Water (no susp. part.)	360
Water Solubility	5,468 g/m^3	Bulk Soil	720
Vapor Pressure	12,000 Pa	Bulk Sediment	3,240
Melting Point	-81.22° C		

† Distribution for MSBE is based on the following model input parameters, reaction half-life in hours as predicted using EPI SuiteTM (2000), and a model default emission rate of 1000 kg/hr into each of the air, water, and soil compartments:

Molecular Weight	88.15	Reaction half-life (hr):	
Temperature	25° C	Air (gaseous)	7.6
Log K_{ow}	1.47	Water (no susp. part.)	360
Water Solubility	16,400 g/m^3	Bulk Soil	720
Vapor Pressure	27,730 Pa	Bulk Sediment	3,240
Melting Point	-100° C		

Conclusion

Results of the Mackay Level I model suggest that the predominant constituents of the C3-5 BIR stream will partition primarily to the air, >91%. These results are largely explained by their vapor pressures. In comparison, the Level III model suggests that the majority of the C3-5 BIR stream will partition to the water compartment, approximately 51 to 65%, followed by the soil compartment at approximately 19 to 28%, and air compartment at approximately 7 to 26%. These results are explained by the model

parameters, but in particular the default emission rates and degradation half-lives.

C. Aquatic Toxicity Data

Data are available to characterize the potential freshwater fish acute, invertebrate acute, and freshwater alga toxicity of the C3-5 Butene-Isobutylene Rich stream, based on data for three constituents, MTBE, TAME, and MSBE (Tables 5 through 7).

MTBE demonstrated a measured 96-hour fathead minnow (*Pimephales promelas*) LC_{50} toxicity value of 672 mg/L (Geiger, *et al*, 1988) and a measured 48-hour invertebrate (*Daphnia magna*) EC_{50} toxicity value of 651 mg/L (Huels AG, 1991b). The lowest green alga (*Selenastrum capricornutum*) 72-hour EC_{50} toxicity value was for growth rate and measured >800 mg/L (ECB data). The 72-hour NOEC value from this study was 470 mg/L (Huels AG, 1991c).

The measured MTBE data were compared with data calculated (Table 5) by the ECOSAR model (2004). This model is considered appropriate to estimate the aquatic toxicity for this class of chemicals. The calculated data compared favorably with the measured data. The calculated freshwater fish acute, invertebrate acute, and freshwater alga toxicity values ranged between 140 to 231 mg/L.

Table 5. Measured and calculated aquatic toxicity values for MTBE (methyl-tert-butyl ether).

ENDPOINT	MEASURED VALUE (mg/L)	CALCULATED VALUE* (mg/L)
Fish 96-hr LC_{50}	672 (Geiger, *et al*, 1988)	224
Daphnid 48-hr EC_{50}	651 (Huels AG, 1991b)	231
Alga 72-hr ErC_{50}	>800 (ECB data)	na
Alga 96-hr EC_{50}	na	140
Alga 72-hr NOEC	470 (ECB data)	na
Alga 96-hr ChV**	na	10**

na - not available

* Model input parameters for ECOSAR (2004):
Log K_{ow} 0.94
Water Solubility 51,000 g/m^3
Melting Point -108.6° C

** ChV (chronic) value

TAME demonstrated a measured 96-hour trout (*Oncorhynchus mykiss*) LC_{50} toxicity value of 580 mg/L (API, 1995a) and a measured 48-hour invertebrate (*Daphnia magna*) EC_{50} toxicity value of 100 mg/L (API, 1994). The lowest green alga (*Selenastrum capricornutum*) 72-hour EC_{50} toxicity value was for biomass and measured 230 mg/L (Fortum, 2003). The 72-hour NOEC value from this study was 77 mg/L.

The measured TAME data were compared with data calculated (Table 6) by the ECOSAR model (2004). This model is considered appropriate to estimate the aquatic toxicity for this class of chemicals. The calculated data compared favorably with the measured data. The calculated freshwater fish acute, invertebrate acute, and

freshwater alga toxicity values ranged between 127 to 208 mg/L.

Table 6. Measured and calculated aquatic toxicity values for TAME (tert-amyl methyl ether).

ENDPOINT	MEASURED VALUE (mg/L)	CALCULATED VALUE* (mg/L)
Fish 96-hr LC_{50}	580 (API, 1995a)	201
Daphnid 48-hr EC_{50}	100 (API, 1994)	208
Alga 72-hr EbC_{50}	230 (Fortum, 2003)	na
Alga 96-hr EC_{50}	na	127
Alga 72-hr NOEC	77 (Fortum, 2003)	na
Alga 96-hr ChV**	na	10**

na - not available

* Model input parameters for ECOSAR (2004):
Log K_{ow} 1.55
Water Solubility 5,468 g/m^3
Melting Point -81.2° C

** ChV (chronic) value

Measured acute aquatic toxicity data were not available for MSBE (Table 7). Calculated acute and chronic toxicity values are reported in Table 7, and were generated by the ECOSAR model (2004). This model is considered appropriate to estimate the aquatic toxicity for this class of chemicals. The calculated data compared favorably with the measured and calculated data for MTBE and TAME. The calculated freshwater fish acute, invertebrate acute, and freshwater alga toxicity values ranged between 9.5 to 213 mg/L.

Table 7. Measured and calculated aquatic toxicity values for MSBE (methyl-sec-butyl ether).

ENDPOINT	MEASURED VALUE (mg/L)	CALCULATED VALUE* (mg/L)
Fish 96-hr LC_{50}	na	206
Daphnid 48-hr LC_{50}	na	213
Alga 96-hr EC_{50}	na	129
Alga 96-hr ChV**	na	9.5

na - not available

* Model input parameters for ECOSAR (2004):
Log K_{ow} 1.47
Water Solubility 16,400 g/m^3
Melting Point -100° C

** ChV - chronic value

Conclusion

The predominant constituents of the C3-5 Butene-Isobutylene Rich stream include the methoxypentanes (3 constituents), which when combined can comprise up to 97% of the stream, will be responsible for the biological effects exhibited by the stream as a whole. Therefore, the effect range characterized by the data represents the potential aquatic toxicity of the C3-5 BIR stream, which can range from 9.5 to 231 mg/L.

D. Mammalian Toxicity Data

Acute Toxicity

Data are available to characterize the potential acute toxicity of the C3-5 Butene-Isobutylene Rich stream, based on data for three constituents, MTBE, TAME, and MSBE. The oral rat LD_{50} values for MTBE and TAME were approximately 3900 mg/kg (ARCO, 1980), and 2100 mg/kg (Daughtrey and Bird, 1995), respectively. The dermal LD_{50} values for MTBE and TAME were >10000 mg/kg (ARCO, 1980) and >3160 mg/kg (ExxonMobil, 1985a), respectively. The inhalation rat LC_{50} value for MTBE and TAME were 8.5 mg/L (Mastri, *et.al*., 1969) and >5.4 mg/L (Amoco, 1991a). An additional inhalation exposure of mice to MSBE resulted in an LC_{50} of 141,000 mg/m^3 (Marsh & Leake, 1950).

In summary, available acute toxicity data on predominant constituents of the C3-5 Butene-Isobutylene Rich stream demonstrated a low order of acute oral, dermal, and inhalation toxicity. No further testing is proposed.

Genotoxicity

In vitro

MTBE has been extensively tested for genotoxicity in a variety of *in vit*ro test systems. Although all results have not been consistently negative, the conclusion is that the substance is not a genotoxicant (ECB, 2002; ARCO, 1980). TAME, was also negative in a bacterial reverse gene mutation assay (Ames test) in *Salmonella typhimurium* and/or *Escherichia coli* with and without S-9 metabolic activation (Brooks et al., 1982; Daughtrey and Bird, 1995; OECD, 2002). No data was available for MSBE.

TAME was also tested in an *in vitro* Mammalian Chromosomal Aberration Test (American Petroleum Institute, 1997b). In this study, TAME was tested in cultured Chinese hamster ovary (CHO) cells for induction of chromosomal aberrations, both in the presence and absence of Aroclor 1254-induced Sprague-Dawley rat liver S9. The test included concurrent solvent and positive controls and five doses of TAME. The doses tested were 313, 625, 1250, 2500, and 5000 μg/ml. In the absence of S9, a statistically significant increase in aberrant cells was observed at 2500 and 5000 ug/ml, and a dose response was observed. In the presence of S9, a statistically significant increase in aberrant cells was observed at all concentrations, and a dose response was observed. In conclusion, based on these results, TAME was clastogenic under the conditions of this assay.

In vivo

MTBE has also been extensively tested for genotoxicity in a number of *in viv*o test systems. Again, all results have not been consistently negative, however, the conclusion is that the substance is not a genotoxicant (ECB, 2002; McKee *et.al*., 1997).

TAME was evaluated *in vivo* for its ability to induce micronuclei in bone marrow polychromatic erythrocytes (PCEs) in CD-1 mice (Daughtrey and Bird, 1995). TAME was diluted in corn oil and administered as a single intraperitoneal injection at doses of 0.15, 0.375, and 0.75 g/kg. Cyclophosphamide was dissolved in water and used as the positive control at a dose of 40 mg/kg. Animals from the appropriate groups were euthanized by CO_2 at approximately 24, 48 and 72 hours after administration of test article. Animals dosed with cyclophosphamide were taken at 24 hours only. Each group consisted of 10 animals (5/sex/group) per time point. At death, both femurs from each animal were removed and bone marrow was recovered and suspended in fetal bovine serum. Bone marrow slides were prepared and stained with acridine orange prior to microscopic evaluation. One thousand polychromatic erythrocytes from each animal were examined for micronuclei formation. In addition, the ratio of polychromatic erythrocytes (PCEs) to normochromatic erythrocytes (NCEs) was determined by counting 1000 erythrocytes (PCEs and NCEs). No increase in microcucleus frequency was observed at any dose level of TAME or at any of the bone marrow collection times. The positive control produced statistically significant increases in micronucleus frequencies in both males and females. Overt marrow toxicity, as measured by a statistically significant decrease in the percentage of polychromatic erythrocytes, was not observed in any of the groups dosed with TAME. The percentages of polychromatic erythrocytes observed were within the normal range. Thus, these data indicated that TAME did not cause clastogenic effects in mouse bone marrow.

In summary, *in vitro* and *in vivo* genotoxicity testing of MTBE demonstrated no evidence of genotoxicity. TAME was not mutagenic in an *in vitro* Ames assay but was found to be clastogenic in an *in vitro* chromosome aberration study. However, as no evidence of genotoxicity was observed in an *in vivo* mouse micronucleus test, the weight of evidence suggests that TAME is not a mutagen. No data was available on the genotoxicity of MSBE. Based on these data on predominant constituents, no additional testing on the C3-5 Butene-Isobutylene Rich stream is proposed.

Repeated Dose Toxicity

A number of repeated dose toxicity studies have been conducted on MTBE and TAME.

In repeated dose toxicity studies with MTBE, the principal affected organs are the liver and the kidneys, mainly at inhaled concentrations of 3,000 ppm and above or at oral doses of 250 mg/kg or higher (ECB, 2002; Greenough, *et. al.*, 1980; Robinson, *et.al*., 1990). MTBE produced protein droplet nephropathy, probably associated with the male rat specific accumulation of α2u-globulin in tubular cells. MTBE increased liver weight and induced hepatocyte hypertrophy in rats and mice. In female mice, MTBE induced a variety of microsomal P450 activities without hepatotoxicity or an increase in sustained nonfocal hepatocyte DNA synthesis (ECB, 2002).

A 28-day repeated dose inhalation toxicity study was conducted with TAME vapor in Sprague-Dawley rats (Amoco, 1991a; White *et al.*, 1995). In this study, the rats

(14/sex/group) were exposed to TAME vapor at target concentrations of 0, 500, 2000, and 4000 ppm for 6 hours per day, 5 days per week for 4 weeks. Three out of 14 males and 4 out of 14 females in the 4000 ppm group died during the study, three animals during the first week, two during the second week and two during the third week. The 2000 ppm and 4000 ppm groups showed signs of central nervous system depression as well as other signs of toxicity, e.g., lacrimation, dyspnea, rales, diarrhea, piloerection, etc. Significant decreases in body weight gain were observed in the 4000 ppm males resulting in significantly reduced mean body weights during weeks 2 - 4. No other significant effects on body weight were reported. Evaluation of gross pathology revealed that absolute brain weights were significantly decreased in the 4000 ppm males and that absolute liver weights were significantly increased in the 2000 ppm males and 4000 ppm females. Many relative organ weights were increased for the 4000 ppm males due to the reduced body weights of these animals. No treatment-related histopathological findings were noted. TAME produced minimal effects on clinical chemistry and hematology parameters. A No Observed Adverse Effect Level (NOAEL) of 500 ppm was determined in this study.

A 28-day repeated oral dose toxicity study was conducted with TAME in Sprague-Dawley rats (Daughtrey and Bird, 1995). In this study, the rats (5/sex/group) were dosed with 0, 125, 500, and 1000 mg/kg TAME in corn oil by gavage at a dose volume of 2 ml/kg. Vehicle control animals received corn oil only. The dosing regimen was once daily, 7 days a week, for a period of 29 days.

Four animals (two male, two female) in the high-dose group died during the course of the study. Of these four, two deaths were attributed to dosing accidents. The remaining two deaths were presumed to be test material-related, although a precise cause of death could not be identified. All other animals survived to the scheduled termination. Overall, in-life observations were unremarkable. Lung rales and anogenital staining of the fur were observed at a low frequency in the high-dose group. The majority of animals of either sex did not exhibit any unusual symptoms or behaviors. Mean body weights of high-dose males were significantly lower than those of control males at day 7, day 21, and day 28. Mean body weight gain in high-dose females was also lower than in control females, although the difference was not statistically significant. Food consumption in high-dose males and females was also significantly reduced compared to controls during week 1. During week 2, food consumption was significantly reduced only in high dose males. A dose-related increase in adrenal weights was observed that was statistically significant in the mid- and high-dose males. A similar increase in adrenal weights was not observed in female rats dosed with TAME. Relative kidney weights were also increased in mid- and high-dose male rats compared to control.

Hematology and serum chemistry values were generally similar across dose groups. Activated partial thromboplastin time was statistically increased in the high-dose male (but not female) group. However, this small increase was not believed to be biologically meaningful. The mean serum glucose value was also significantly reduced in the high-dose male group. The biological significance of this finding was unknown, however a similar decrease in serum glucose was not observed in high-dose females. No treatment-related tissue lesions were observed during the histopathological examination. Any changes observed were limited to naturally occurring lesions that were present in approximately equal frequency in all groups, including controls. Of

note, the organ weight increases observed in the kidney and adrenals were not accompanied by any histopathological changes. The NOAEL in this study was determined to be 500 mg/kg/day.

In a 13-week repeated dose toxicity study conducted by the American Petroleum Institute (1997a), F344 rats (51/sex - control and high dose; 41/sex - low and mid-dose) and CD-1 mice (46/sex -control and high dose; two groups each; 36/sex -low and mid-dose) were exposed by whole body inhalation to TAME at target concentrations of 0, 240, 1500, and 3500 ppm for 6 hours/day, 5 day/week for 13 weeks (minimum 65 exposures). A new high dose group of mice at 2500 ppm and corresponding control group were established due to high mortality at 3500 ppm. The results for rats and mice are presented separately.

In rats, a number of effects were observed at the highest dose used, 3500 ppm. These effects included a low incidence of mortality (2/102), abnormal clinical signs (lethargy and prostration), acute neurological effects, decreased body weight and body weight gain, effects on hematology (increased platelet counts), effects on clinical chemistry (increases in total protein, albumin and globulin), and a number of effects on organ weights. The effects on the kidneys of the male rats were consistent with the male rat specific α2u-globulin syndrome and were not considered to be relevant to risk assessment in humans. Exposure of rats at 1500 ppm resulted in effects including post exposure clinical signs, acute neurological effects (males only), increased platelet count in males, increases in total protein, albumin and globulin and effects on liver and kidney (only in females) weight. An increase in liver weights of male rats exposed to 250 ppm was also observed. Many of these resolved after the 4 week recovery period. On histopathological examinations, no dose-related changes were observed in the liver. No test material-related changes in motor activity were observed at any doses. The NOAEL for rats was 1500 ppm in this study.

In this study, high mortality was observed in mice exposed to 3500 and 3000 ppm. A number of effects were observed at the highest dose used in the main study, 2500 ppm. These included 27 deaths among 92 mice, post-exposure clinical signs, effects on a number of clinical chemistry parameters, and increased liver weights. Exposure of mice at 1500 ppm resulted in effects including post exposure clinical signs, increased globulin in males at week 6 and effects on liver weights in males. Many of these resolved after the 4 week recovery period. Liver cell proliferation studies showed increases in the labelling index of hepatocytes and centrilobular hepatocellular hypertrophy was observed in the 2500, 1500 and 250 ppm animals. Centrilobular hepatocellular hypertrophy is considered an adaptive response to increased metabolic load. The NOAEL for mice was determined to be 1500 ppm.

In summary, data are available to adequately characterize the repeated dose toxicity of C3-5 Butene-Isobutylene Rich stream. The C3-5 BIR stream is expected to have a low order of repeated dose toxicity. No further testing is proposed.

Reproductive and Developmental Toxicity

Predominant constituents of the C3-5 Butene-Isobutylene Rich stream have been evaluated for reproductive and developmental toxicity.

MTBE has been tested for effects on fertility in one- and two-generation studies in Sprague-Dawley rat via the inhalation route. The NOAEL for F1-animals in the one-generation study was 250 ppm; a lowered pup viability index was seen at a LOAEL of 1,000 ppm (Biles, *et.al*., 1987; OECD, 2002). In the two-generation study, a NOAEL of 400 ppm was determined for both the F1- and F2-animals (Bevan, *et.al,* 1997; ECB, 2002). The only effects seen at the LOAEL were reduced body weight at 3,000 ppm and increased relative liver weight.

Developmental toxicity of MTBE has been tested via the inhalation route in rats, mice and rabbits. There were no adverse effects noted in the Sprague-Dawley rat at 2,500 ppm or the CD-1 mouse at 1,000 ppm (Conaway, *et.al,* 1985; ECB, 2002). Sternebrae malformations observed in CD-1 mice at 250 to 2,500 ppm were not considered treatment related. Reduced body weight and skeletal abnormalities were seen in CD-1 only at 4,000 ppm, a dose level already toxic to dams (Bevan, *et.al*, 1997; ECB, 2002). Likewise, no adverse effects to the developmental of New Zealand White rabbits could be demonstrated, even at 8,000 ppm (Bevan, *et.al*, 1997; ECB, 2002).

A two-generation reproductive toxicity study of inhaled TAME vapor was conducted in Sprague-Dawley rats (Tyl *et al.*, 2003). In this study, weanling F0 rats (30/sex/group) inhaled TAME vapor at 0, 250, 1500, or 3000 ppm 5 day/week and 6 h/day for 10 weeks, with vaginal cytology evaluated for weeks 8-10. The F0 animals then produced F1 offspring, with exposure 7 days a week from mating through to lactation. During the F1 prebreed exposure period, vaginal patency, preputial separation (PPS) and vaginal cytology were evaluated. The F1 animals were mated, with F2 anogenital distance measured on postnatal day zero. At F2 weaning 30 of each gender per group were selected for postwean retention, with no exposures, through vaginal patency and PPS. Body weights, feed consumption and clinical signs were recorded throughout the study. Adult F0 and F1 systemic toxicity was present at 1500 and 3000 ppm. Minor adult male reproductive toxicity was present at 3000 ppm. There were no adult effects on vaginal cyclicity, estrous cycle length, mating, fertility, pregnancy, gestational length or ovarian and uterine weights. There were no treatment-related gross or histopathologic findings in parental male or female systemic or reproductive organs. Offspring toxicity was present at 1500 and 3000 ppm. The NOAEL for adult reproductive toxicity was 1500 ppm for males and 3000 ppm for females. The NOAEL for offspring toxicity was 250 ppm in rats under the conditions of this study.

A developmental toxicity study was conducted by TAME vapor inhalation exposure in two pregnant rodent species (Welsch *et al.*, 2003). Timed-pregnant Sprague-Dawley rats and CD-1 mice, 25 animals per group, inhaled TAME vapors containing 0, 250, 1500, or 3500 ppm for 6 hours a day on gestational days (gd) 6-16 (mice) or 6-19 (rats). The developmental toxicity hazard potential was evaluated following the study design draft guidelines and end points proposed by the United States Environmental Protection Agency.

In the present study, inhalation of TAME by pregnant rats from gestational days 6-19 resulted in manifestations of maternal toxicity at 1500 and 3500 ppm. These effects were expressed by reductions in body weight (at 3500 ppm only), feed consumption and weight gain, and TAME exposure-induced clinical signs of toxicity. There was no evidence of maternal toxicity at 250 ppm. The increased maternal relative liver weight

at 3500 ppm that occurred when maternal body weight was actually reduced may be due to induction of metabolizing enzymes and a concurrent increase in liver mass. There was a clear indication of maternal accommodation to the highest TAME exposure concentration, as evidenced by diminution in incidence and intensity of clinical signs such as ataxia, lethargy and slow respiration over time. Developmental toxicity occurred only at 3500 ppm and was expressed as reduced fetal body weights per litter. There was no evidence of treatment-related teratogenicity at any of the three exposure concentrations and no other developmental effects. Almost all of the fetal malformation and variation findings were those commonly observed in historical control Sprague-Dawley rat fetuses and in published control databases. Therefore, the NOAEL was 250 ppm for maternal toxicity and 1500 ppm for developmental toxicity in rats under the conditions of this study.

In mice, the inhalation of TAME vapors during gd 6-16 resulted in maternal toxicity at 3500 ppm, including maternal mortality (4/25), reductions in body weight, weight gain and treatment-related clinical signs of toxicity. At 1500 ppm, mice exhibited reduced feed consumption (only for gd 6-9) and limited treatment-related clinical signs of toxicity. There was no evidence for maternal toxicity at 250 ppm. The increased maternal absolute and relative liver weights at 1500 and 3500 ppm may have been due to induction of metabolizing enzymes and therefore increase in tissue mass. There was also a clear indication of reduced pharmacological effects with time and maternal accommodation to the top two exposure concentrations. This interpretation was supported by observations of mortality at 3500 ppm early in the exposure period (gd 6-9) only and diminution over time in the incidence of clinical signs of toxicity, such as ataxia, lethargy, gasping and slow respiration. The increased relative liver weight may have been due, at least in part, to the reduced body weights of the dams at termination at 3500 ppm. Developmental toxicity was present at 3500 ppm, expressed specifically as increased incidence of late fetal deaths, reduced fetal body weights per litter and increased incidences of cleft palate (an external malformation) and of enlarged lateral ventricles of the cerebrum (a visceral variation). At 1500 ppm, three fetuses in three litters also exhibited cleft palate (with none observed at 250 or 0 ppm). This increase was not statistically significant, but it is considered biologically relevant and related to maternal TAME exposure. The finding of one additional litter at 1500 ppm with three multiply malformed fetuses (out of nine live fetuses total) may be unrelated to treatment because these malformations were not observed at 3500 ppm and were limited to only one litter at 1500 ppm. The observation of cleft palate in fetuses at 1500 and 3500 ppm appears to be consistent with a proposed mechanism for cleft palate in mice exposed to methyl tertiary butyl ether (MTBE). Maternal exposure to MTBE with anesthetic qualities at high concentrations associated with maternal stress results in elevated endogenous corticosteroid levels, which cause cleft palate to the developing offspring in mice (Bevan *et al.*, 1997). Although those hormone levels were not determined in the present study, the biological mode of action of TAME appears to be similar and comparable to that of MTBE, as judged by clinical observations. At high exposure concentrations in mice, TAME exerts depressant effects on the central nervous system that resemble anesthetic properties and are preceded by a pronounced excitatory stage. Therefore, the brain stimulation and excitation may have induced a rise in endogenous corticosteroid levels in the mouse dams. The occurrence of a significantly increased incidence of fetal cleft palate at the 3500 ppm exposure level, coincident with maternal toxicity, suggests that stress of the dams is a contributing factor. Mice are

sensitive to stress, and cleft palate occurs in offspring if the pregnant dams experience stress such as food and water deprivation, transportation, restraint or low humidity. That corticosteroids cause cleft palate in susceptible mouse strains is well documented. The increased incidence of enlarged lateral ventricles of the fetal cerebrum at 3500 ppm is consistent with developmental delay because the fetuses at this exposure concentration exhibited mean body weights per litter of about 60% of the concurrent control group values. There were no notable developmental effects at 250 ppm. Therefore, the NOAEL for maternal and developmental toxicity in mice was 250 ppm in the present study.

The available data on predominant constituents of the C3-5 Butene-Isobutylene Rich stream prove adequate to support a screening level assessment of the reproductive and developmental toxicity of the C3-5 BIR stream. Furthermore, these data indicate that the C3-5 BIR stream is expected to have a low order of reproductive and developmental toxicity.

Conclusion

Mammalian toxicology data on three constituents of the C3-5 BIR stream, MTBE, TAME, and MSBE, have shown a low order of acute toxicity by the oral, dermal and inhalation routes of exposure. In repeated dose toxicity studies, the principal affected organs are the liver and the kidneys, mainly at inhaled concentrations of 3,000 ppm and above or at oral doses of 250 mg/kg or higher. Repeated exposure to these constituents is not expected to cause significant harm to reproduction or the developing fetus. There is no evidence of causing adverse effects on genetic material. The available data compiled for predominant constituents prove adequate to support a screening level hazard assessment of the C3-5 BIR stream. Therefore, no additional human health toxicity testing is proposed.

Table 8. Mammalian toxicity endpoint summary for MTBE.

TOXICITY ENDPOINT		RESULTS	REFERENCE
Acute	Inhalation	LC50 85 mg/L	Mastri, *et. al*., 1969
	Oral	LD50 = ~3866 mg/kg	ARCO, 1980
	Dermal	LD50 >10000 mg/kg	ARCO, 1980
Irritation	Skin	Moderate irritant	ARCO, 1980
	Eye	Minimal irritant	ARCO, 1980
Sensitization		Not a dermal sensitizer	Litton Bionetics Inc., 1980
Repeated Dose		Inhalation: NOAEL = 500 ppm Oral: NOAEL = 357 ppm	
Reproductive		NOAEL for adult toxicity = 250 ppm (1-Gen) = 400 ppm (2-Gen) NOAEL for offspring toxicity = 250 ppm (1-Gen) = 400 ppm (2-Gen)	Biles, *et al.*, 1987; Bevan, *et.al*, 1997; ECB, 2002
Developmental		NOAEL developmental toxicity = 2500 ppm (rat) 1000 ppm (mouse) 1000 ppm (rabbit) NOAEL developmental toxicity = 2500 ppm (rat) 1000 ppm (mouse) >8000 ppm (rabbit)	Conaway, *et al.*, 1985; Bevan, *et.al*, 1997; ECB, 2002
Neurotoxicity		Acute CNS depression were only observed at high doses immediately after exposure. All effects were mostly reversible within 6 hours.	Gill, 1989; ECB, 2002
Genotoxicity	*In vitro* Ames *Salmonella* assay	Negative	ECB, 2002
	In vitro chromosome aberration	Negative - MTBE was not clastogenic under the conditions of this assay	ECB, 2002; ARCO, 1980
	In vivo micronucleus	Negative - in CD-1 Mice erythrocytes	ECB, 2002; McKee,*et. al.,* 1997

Table 9. Mammalian toxicity endpoint summary for TAME.

TOXICITY ENDPOINT		RESULTS	REFERENCE
Acute	Inhalation	LC50 >5.4 mg/L	Amoco, 1991a
	Oral	LD50 = ~2100 mg/kg	Daughtrey and Bird, 1995
	Dermal	LD50 >3160 mg/kg	ExxonMobil, 1985a
Irritation	Skin	Minimal irritant	Amoco, 1991b
	Eye	Minimal irritant	ExxonMobil, 1985b
Sensitization		Not a dermal sensitizer	American Petroleum Institute, 1995b
Repeated Dose		Rat: NOAEL = 1500 ppm Mouse: NOAEL = 1500 ppm	American Petroleum Institute, 1997a
Reproductive		NOAEL for adult reproductive toxicity = 1500 ppm (males), >3000 ppm (females) NOAEL for offspring toxicity = 250 ppm	Tyl *et al.*, 2003
Developmental		NOAEL for maternal toxicity = 250 ppm (rat, mouse) NOAEL developmental toxicity = 1500 ppm (rat), 250 ppm (mouse)	Welsch, 2003
Neurotoxicity		Acute CNS depression were only observed at high doses immediately after exposure. All effects were completely reversible within 24 hours.	American Petroleum Institute, 1997a
Genotoxicity	*In vitro* Ames *Salmonella* assay	Negative	Daughtrey and Bird, 1995
	In vitro chromosome aberration	Positive - TAME was clastogenic under the conditions of this assay	American Petroleum Institute, 1997b
	In vivo micronucleus	Negative - TAME was not clastogenic to mouse bone marrow	Daughtrey and Bird, 1995

Table 10. Mammalian toxicity endpoint summary for MSBE.

TOXICITY ENDPOINT		RESULTS	REFERENCE
Acute	Inhalation	LC50 = 141,000 mg/m^3	Marsh and Leake, 1950
	Oral		
	Dermal		
Irritation	Skin		
	Eye		
Sensitization			
Repeated Dose			
Reproductive			
Developmental			
Neurotoxicity			
Genotoxicity	*In vitro* Ames *Salmonella* assay		
	In vitro chromosome aberration		
	In vivo micronucleus		

IV. TEST PLAN SUMMARY

A search for existing studies/information identified adequate data to characterize all endpoints under the U.S. EPA HPV Program using data from representative constituents of the predominant fractions in the C3-5 BIR stream. The three constituents were MTBE, TAME, and MSBE. Adequate data for MTBE, TAME, and MSBE are shown in Table 11.

Table 11. MTBE**,** TAME, and MSBE data availability and adequacy for endpoints in the HPV Program.

	Mammalian Toxicity						**Environmental Toxicity**			**Environmental Fate**				**Physical/Chemical Properties**					
	Acute Tox.	Genetic Pt. Mut.	Genetic Chrom.	Repeat Dose	Devel.	Repro.	Acute Fish	Acute Invert.	Alga Tox.	Photo-deg.	Hydrol.	Fug.	Biodeg.	Melt. Pt.	Boil. Pt.	Dens.	Vap. Pres.	Water Sol.	K_{ow}
MTBE	**A**	**A**	**A**	**A**	**A**	**A**	**A/C**	**A/C**	**C**	**T**	**T**	**C**	**A**	**A**	**A**	**A**	**A**	**A**	**A**
TAME	**A**	**A**	**A**	**A**	**A**	**A**	**A/C**	**A/C**	**C**	**T**	**T**	**C**	**A**	**A**	**A**	**A**	**A**	**A**	**A**
MSBE	**A**	**-**	**-**	**-**	**-**	**-**	**C**	**C**	**C**	**T**	**T**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**

A Adequate measured data available
C Adequate computer model data available
T Adequate technical discussion available

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