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Examining Thermolytic Production of Hydrogen from Lubrication Oil

S. C. Hunter

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PREFACE OR ACKNOWLEDGEMENTS

The author wishes to acknowledge the efforts of all those involved in the planning, design, performance, analysis, and documentation of this research. Meagan Kinard expertly performed the experiments described herein. When Meagan was unavailable, Daniel Jones was able to step in and help with the testing. John Pareizs served invaluably as the process expert for the gas chromatography columns employed during these tests. Matt Williams supplied his valued help as the process expert for the infrared spectrometer. Holly Hall served as the facility coordinator, ensuring that the increasing demand for resources could always be fulfilled. Amy Blunt managed the samples and materials generated through the course of this research. Wesley Woodham graciously provided his valuable knowledge on the process, testing and analysis.

EXECUTIVE SUMMARY

The Savannah River National Laboratory (SRNL) performed testing to investigate the thermolytic production of hydrogen gas from the addition of Mobil SHC 630 into caustic simulants. Currently, 35 gallons of contaminated lubrication oil, Mobil SHC 630, is proposed for release into the recycle stream from the Defense Waste Processing Facility (DWPF) to Tank 22 and then to the 242-16H (2H) Evaporator system. The following conclusions were drawn below from the thermolytic Hydrogen Generation Rate (HGR) tests.

- In an HGR test that mimics a 50-gallon Mobil SHC 630 addition to the recycle pump tank (RPT) at heel, the observed HGR in the Tank 22 simulant was indistinguishable from the Oil-Free HGR, suggesting that Mobil SHC 630 would not be expected to have a significant contribution to the overall flammability of the vapor space.

- In thermolytic HGR tests with approximately 50 mg/L of Mobil SHC 630, in a Tank 38 simulant at 100 °C as well as tests in a high hydroxide simulant at 100 and 140 °C to mimic evaporator conditions, the thermolytic HGR attributable to Mobil SHC 630 appears to be bounded by the Global TOC model.

- From all applicable tests, no volatile degradation products, including methane, were observed in the offgas.

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LIST OF ABBREVIATIONS

ACTL	Aiken County Technology Laboratory
CSTF	Concentration, Storage, and Transfer Facilities
DI	deionized
DWPF	Defense Waste Processing Facility
FTIR	Fourier transform infrared
GC-TCD	Gas Chromatography-thermal conductivity detector
HGR	Hydrogen Generation Rate
LPPP	Low Point Pump Pit
M&TE	Measuring and Test Equipment
PAO	polyalphaolefin
PTFE	polytetrafluoroethylene
RCT	Recycle Collection Tank
RPT	Recycle Pump Tank
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation
SRS	Savannah River Site
TOC	Total Organic Carbon
TTR	Technical Task Request

1.0 Introduction

Savannah River National Laboratory (SRNL) was requested by Savannah River Remediation (SRR) to conduct testing via Technical Task Request (TTR) to determine the thermolytic HGR of Mobil SHC™ 630, a lubrication oil.[1] Currently, 35 gallons of contaminated Mobil SHC 630 is proposed for release into the recycle stream from the Defense Waste Processing Facility (DWPF) to Tank 22 and then to the 242-16H (2H) Evaporator system. Inhibited recycle waste in the Recycle Collection Tank (RCT) is transferred to Recycle Pump Tank (RPT) in the Low Point Pump Pit (LPPP) and then to the Concentration, Storage, and Transfer Facilities (CSTF) H-area. The lubrication oil would be added directly to the RPT, bypassing the RCT. The current DWPF waste compliance plan for liquid transfers from the RCT to the CSTF limits the concentration of Mobil SHC 630 to <1,100 ppm which is equal to <9.3 gallons of Mobil SHC 630 when considering a 7,500 gal RCT batch with an initial Mobil SHC 630 concentration of 42 mg/L.[2,3]

Mobil SHC 630 is expected to be largely immiscible in the caustic aqueous waste stream. It is a blend of base oils including polyalphaolefin (PAO) base oil and additives such as triphenylphosphate and cresyl diphenyl phosphate at various concentrations (<0.25 wt%) (see Appendix A). While the base oils are expected to be largely unreactive in CSTF waste, the triarylphosphates additives would be expected to hydrolyze in the caustic waste, forming diarylphosphates and phenol. The tests described herein were governed by a single Run Plan and will determine thermolytic HGR from the caustic aqueous solution, as well as from any organic phases present.[4]

2.0 Experimental Procedure

2.1 Experimental Apparatus

The work described herein was performed using the same custom-designed reaction apparatus used in previous testing.[5] All testing was conducted at SRNL facilities within the Aiken County Technology Laboratory (ACTL). A schematic of the apparatus is shown in Figure 2-1. The apparatus consists of a 1.2L polytetrafluroethylene (PTFE) vessel and lid. Fitted to the center of the lid was a Parr® high-torque magnetic drive connected to a PTFE agitator impeller and shaft used to mix the simulant inside the vessel. The speed of the agitator was 200 rpm. Surrounding the magnetic drive were eight ports with stainless-steel fittings used for the following: temperature control within the vessel by two Incoloy® 800 heating rods, monitoring liquid temperature within the vessel with an Inconel® 600 thermocouple, providing purge gas to continuously sweep the vapor space of the vessel, connecting the headspace of the vessel to a glass condenser, providing a route for reflux from the condenser back to the reaction vessel, and for adding the lubrication oil. Upstream from the reaction vessel, two MKS® mass flow controllers were used to supply CO_2-free compressed air or N_2 cylinder gas containing 0.5 vol % Kr and 20 vol % O_2. Downstream from the reaction vessel, a glass condenser was employed to remove condensable gases from the gas before proceeding to analysis. After passing through the condenser, the gas was sampled and quantified for hydrogen content by an Inficon Micro 3000 GC-TCD (gas chromatograph – thermal conductivity detector). An in-line, gas-phase FTIR was also employed as needed to monitor for potential volatile degradation products.

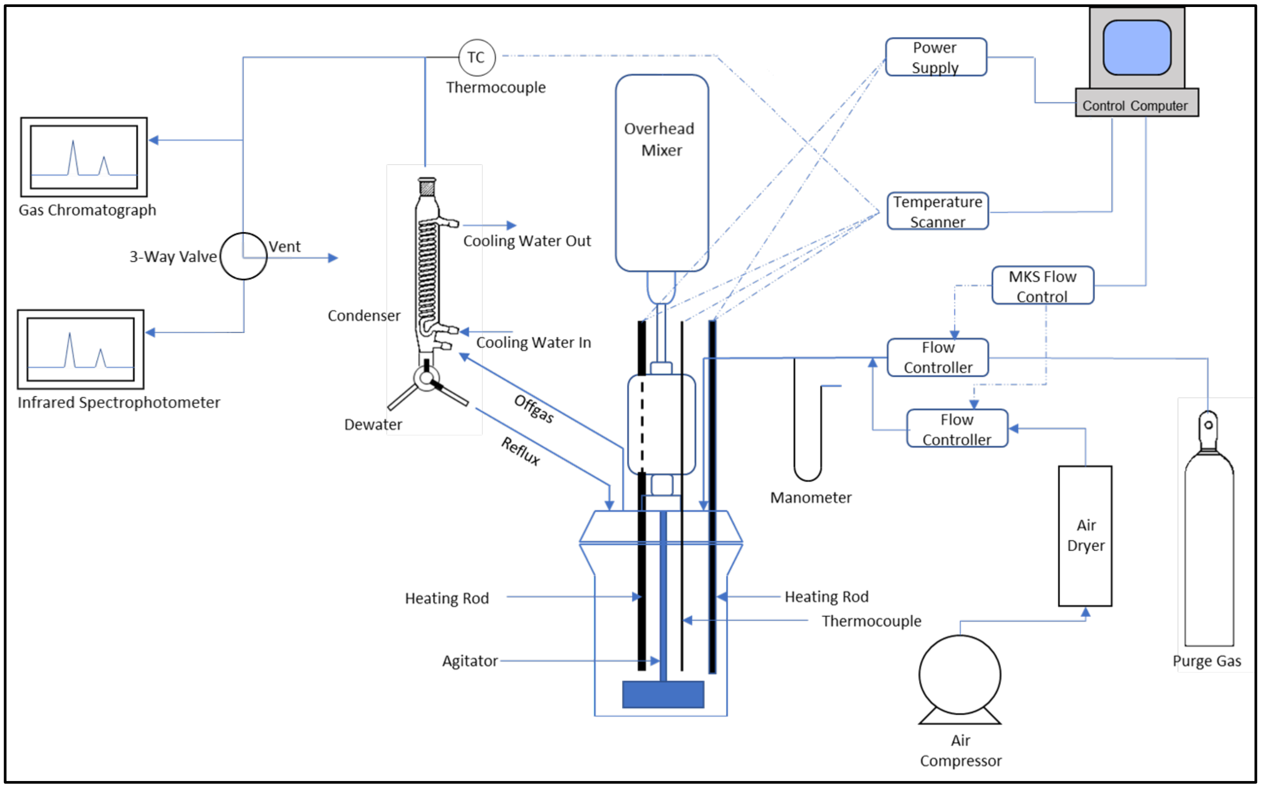

Figure 2-1. Schematic of HGR Measurement Apparatus

2.2 Sample Preparation

Reagent grade sodium nitrate, sodium nitrite, sodium carbonate, and a 50 wt% sodium hydroxide solution were purchased from Fisher Chemical and used as received. In the case where the targeted hydroxide concentration precludes the use of 50 wt% sodium hydroxide solution, solid reagent grade sodium hydroxide was used as the hydroxide feedstock. Reagent grade aluminum trinitrate nonahydrate was purchased from Sigma-Aldrich and used as received. Reagent grade sodium sulfate was purchased from Alfa Aesar and used as received. The reagents were added directly to the reaction vessel before sealing. The order of addition to the vessel was as follows: sodium hydroxide and half of the deionized (DI) water prior to the aluminum source, then the remaining species and remaining DI water.

2.3 Experimental Procedure

After the addition of all chemicals, the vessel was sealed and checked for leaks by mass balance of air flow through the process headspace. Once leak-free conditions had been confirmed, stirring was initiated and a purge flow of dried air was applied to the process to sweep residual CO_2 out of the vessel. The system controls were then set to apply heat via two electric heating rods such that the difference between the process (fluid) temperature and that of the heating rod interior could not exceed 30 °C. In experimental tests, the process fluid was brought to the desired temperature, at which point either the lubrication oil was added or not (blank tests). The purge gas was then switched to the typically lower-purge process gas stream (0.5 vol % Kr and 20 vol % O_2 in N_2). This point was designated as the start of the experiment.

The experiment continued while monitoring for hydrogen concentration via GC. The experiment duration was planned such that at a minimum, the vessel headspace could undergo approximately three vapor space-volume turn-overs (achieving 99.7% of pseudo steady-state, assuming continuously-stirred reactor dynamics; note that this time is volume- and purge rate-dependent). Once this time was reached and hydrogen measurements by GC stabilized or began to decrease, the heating rod power was turned off and the experiment was stopped. The higher-purge air was then reapplied to the vessel to sweep residual hydrogen from the system. The simulant mixture was then removed from the vessel and subsampled as needed for product analyses. Density of the simulant was checked by weighing a known volume of the simulant using an M&TE autopipette and an M&TE balance.

2.4 Offgas Analyses

An Inficon Micro 3000 GC was used to analyze offgas content for all experiments. The GC was equipped with two analysis channels: one using a Molsieve 5A column for H_2, O_2, N_2, CH_4, and Kr analysis, and a second using a PoraPLOT Q column for N_2O and CO_2 analysis. Each column employed a thermal conductivity detector which measured against the background of pure argon (also used as a carrier gas). The GC calibration was verified before each experiment using a calibration gas with a composition of 50 ppm_v H_2, 100 ppm_v CH_4, 0.5 vol % Kr, 1 vol % N_2O, 1 vol % CO_2, and 20 vol % O_2 in N_2.

In addition, FTIR was used to monitor for volatile degradation products. The FTIR was plumbed into the line after the GC.

When presented, HGR is reported in units of standard cubic feet per hour per gallon of simulant mixture ($ft^3\ hr^{-1}\ gal^{-1}$). The purge rates employed during this testing were supplied at standard conditions of 21.11 °C and 1 atm. The HGRs presented herein have been corrected to a standard temperature and pressure of 25 °C and 1 atm.

2.5 Quality Assurance

The customer-identified functional classification for these tasks is Safety Class.[1, 6] Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2. Data was recorded in the electronic laboratory notebook system.[7] The use of Measuring and Test Equipment or Measurement Systems and Equipment was recorded in these notebooks. Measurements, analysis, documentation, and technical review comply with the customer required quality assurance level to support Safety Class use of information contained in this report.[6]

The Data Acquisition and Control (DAC) software employed in this testing was used to control mass flow controllers and electric heating rods as well as record data taken from thermocouples and GC-TCD stations. This software is classified as level D.[8] The DAC software does not perform calculations that are used in this report. The logged data that contributes to HGR calculations are the purge gas flows and the reaction temperature. The purge gas flow instruments, thermocouples, and temperature scanner are in the Measurement and Test Equipment program. Each of these instruments has an alternative reading outside of the DAC software. Data is periodically recorded manually (e.g., every 30 minutes) to supplement the files generated by the software.

Analytical measurements of the gas stream were made using GC and FTIR. The GC and FTIR are in the Measurement Systems and Equipment program and their software is controlled under the requirements of the program.

3.0 Results and Discussion

The conditions used to evaluate HGRs from Mobil SHC 630 are given in Table 3-1. The simulant used in test LOil-1 is based on a Tank 22 supernate sample used in previous HGR testing.[9] This test was performed at 60 °C with a targeted lube oil concentration of 17,000 mg/L. This concentration corresponds to a 50-gallon Mobil SHC 630 addition to an RPT heel of 2,500 gallons. For tests LOil-2-4, a Mobil SHC 630 concentration of 50 mg/L was targeted. This concentration is a reasonably conservative estimate of the overall concentration of the lubrication oil in Tank 38. A Tank 38 simulant at 100 °C, a previously used HGR test condition for comparing common organics found in the tank farm, was used in test LOil-2.[5] A high hydroxide simulant used in previous HGR testing was used for tests LOil-3 and LOil-4 to mimic evaporator conditions.[10]

Table 3-1. HGR Test Conditions

Run Name	LOil-1	LOil-2	LOil-3	LOil-4
Simulant	Tank 22	Tank 38	High Hydroxide	High Hydroxide
Temp (°C)	60	100	100	140
Lube Oil (mg/L)	16.34E+03	54.53	62.39	58.41
[Al] (M)	5.10E-04	8.22E-02	3.84E-01	3.89E-01
[NO_2] (M)	2.41E-01	2.51E+00	1.89E+00	1.92E+00
[SO_4] (M)	6.20E-03	7.05E-02	-	-
[CO_3] (M)	4.62E-02	7.39E-01	-	-
[NO_3] (M)	6.25E-02	1.22E+00	1.60E+00	1.62E+00
[OH] (M)	1.85E-01	2.82E+00	1.96E+01	1.99E+01

The results of the HGR testing are given in Table 3-2. In addition to GC, FTIR was used to monitor for volatile degradation products in the offgas in all tests except LOil-2. The Oil-free HGR is the "blank" test without added Mobil SHC 630. The Observed HGR is the HGR measurement with added Mobil SHC 630. These HGRs were calculated using measurement data (10 data points) within the final hour of testing and their percent relative standard deviation (RSD) is given in Table 3-2. The HGR attributable to Mobil SHC 630 is the difference between the "blank" oil-free HGR measurement and the Observed HGR measurement. The model predicted HGR is the predicted HGR at the conditions tested using the Global Total Organic Carbon (TOC) HGR model[5] shown below in Equation [1]

$$HGR_{TOC} = 2.45 \times 10^{6}[OH]^{0.925}[C_{TOC}]e^{-\frac{82,900}{RT}} \qquad [1]$$

where

HGR_{TOC} is the hydrogen production rate from the thermolysis of other organics in $ft^3\ h^{-1}\ gal^{-1}$,
$[OH]$ is the concentration of hydroxide in mol L^{-1},
$[C_{TOC}]$ is the concentration of organic carbon not attributable to formate, oxalate, or glycolate in mol L^{-1},
R is the ideal gas constant, 8.314 J $mol^{-1}\ K^{-1}$, and
T is the temperature in K.

It should be noted that the Global TOC model was derived by assessing the difference in apparent reactivity of "fresh organics" and those found in the Tank Farm. In comparison to "fresh" organic material, one can expect that the most reactive organic species have degraded in the Tank Farm after years of exposure to caustic environments and radiation fields.

Table 3-2. Results of Testing

Run Name	Simulant	Temp (°C)	"Blank" Oil-Free HGR ($ft^3\ h^{-1}\ gal^{-1}$)	Observed HGR ($ft^3\ h^{-1}\ gal^{-1}$)	HGR Attributed to Lube Oil (Observed - Blank) ($ft^3\ h^{-1}\ gal^{-1}$)	Model Predicted HGR ($ft^3\ h^{-1}\ gal^{-1}$)
LOil-1	Tank 22	60	9.92E-08 (10% RSD)	9.55E-08 (11% RSD)	-	-
LOil-2	Tank 38	100	3.40E-07 (6% RSD)	3.50E-07 (13% RSD)	1.0E-08	6.24E-08
LOil-3	High Hydroxide	100	4.52E-07 (8% RSD)	5.29E-07 (10% RSD)	7.7E-08	4.30E-07
LOil-4	High Hydroxide	140	5.03E-07 (8% RSD)	1.04E-06 (7% RSD)	5.39E-07	5.42E-06

The LOil-1 test yielded a relatively small HGR value of $9.55 \times 10^{-8}\ ft^3\ h^{-1}\ gal^{-1}$, which is smaller than the Oil-Free HGR of $9.92 \times 10^{-8}\ ft^3\ h^{-1}\ gal^{-1}$ for the Tank 22 simulant, making any HGR attributable to the lube oil indistinguishable from the baseline HGR of the simulant itself. Mobil SHC 630 is largely immiscible in the Tank 22 simulant while hydrogen-generating organic thermolysis described by the Global TOC model is expected to primarily occur within the aqueous phase.[5] In an attempt to compare the observed thermolytic HGR in LOil-1 to the Global TOC model, the aqueous phase was sampled after the addition of Mobil SHC 630 and subsequent mixing of the two layers. The [TOC] concentration obtained from the sample, 58 mg/L (RSD = 10%), gives the model predicted HGR of $2.43 \times 10^{-10}\ ft^3\ h^{-1}\ gal^{-1}$. This predicted HGR is well below the HGR limit of detection for the test of approximately $5 \times 10^{-8}\ ft^3\ h^{-1}\ gal^{-1}$.

The small concentration, approximately 50 mg/L, of Mobil SHC 630 used in the Tank 38 and high hydroxide simulant tests appeared to be fully dispersed in the simulant by visual inspection, and comparisons can be made between the HGR from Mobil SHC 630 and the predicted HGR from the Global TOC thermolytic HGR expression at the corresponding test conditions. For LOil-2, the Blank and Observed HGR are statistically indistinguishable from each other; the small difference of $1.0 \times 10^{-8}\ ft^3\ h^{-1}\ gal^{-1}$ between the two measurements is below the model predicted HGR. In the high hydroxide tests, LOil-3 and LOil-4, the HGR attributed to Mobil SHC 630, $7.7 \times 10^{-8}\ ft^3\ h^{-1}\ gal^{-1}$ and $5.39 \times 10^{-7}\ ft^3\ h^{-1}\ gal^{-1}$ respectively, are less than the model predicted HGR. This suggests that Mobil SHC 630 is bounded by the Global TOC thermolytic HGR model.

No methane attributable to Mobil SHC 630 was seen in the offgas by either GC or FTIR in all tests. Additionally, no other volatile degradation products were observed in the offgas monitored by FTIR. Mobil SHC 630 is a PAO base oil with a flash point >210 °C and a vapor pressure of <0.1 mmHg at 20 °C (see Appendix A) and thus is not expected to be a significant contributor to the overall flammability of the vapor space in HLW tanks and evaporators.

4.0 Conclusions

Mobil SHC 630 is proposed for release into the recycle stream from DWPF to CSTF. Thermolytic HGR testing was undertaken to determine the thermolytic HGR attributable to the lubrication oil.

The Tank 22 simulant test used to mimic a 50-gallon Mobil SHC 630 addition to the RPT at heel, had an observed HGR indistinguishable from the Oil-Free HGR, suggesting that Mobil SHC 630 would not be expected to have a significant contribution to the overall flammability of the vapor space.

From applicable tests, the thermolytic HGR contributable to Mobil SHC 630 appears to be bounded by the Global TOC model.

No volatile degradation products including methane were observed in the offgas. This finding is consistent with the observation that the base oil blend, including PAO, is not expected to be very reactive in HLW tanks. Furthermore, Mobil SHC 630 itself is not expected to be a significant contributor to the overall flammability of the vapor space due to its relatively large flash point >210 °C and small vapor pressure <0.1 mmHg at 20 °C.

5.0 Recommendations

The one-time addition of Mobil SHC 630 above current concentration limits to the DWPF recycle stream routed to CSTF of 35-gallons of contaminated Mobil SHC 630 should not be prohibited due to thermolytic HGR concerns. However, the potential influence of the oil and its additives on other site processing facilities should be investigated.

6.0 References

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5. Woodham, W. H.; Martino, C. J. *Evaluation of Thermolytic Production of Hydrogen from Glycolate and Common Tank Farm Organics in Simulated Waste*; SRNL-STI-2019-00605, Revision 1; Savannah River National Laboratory: Aiken, SC, 2020.

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7. Hunter, S. C., Electronic Laboratory Notebook. Aiken, SC, 2020.

8. *Generic Software Quality Assurance Plan Savannah River National Laboratory Classified as GS, PS, Level C, D*; B-SQP-A-00053, Rev. 1; Savannah River National Laboratory: Aiken, SC, 2012.

9. Martino, C. J.; Pareizs, J. M.; Newell, J. D. *Thermolytic Hydrogen Generation Testing of Tank 22 Material* SRNL-STI-2018-00385, Revision 0; Savannah River National Laboratory Aiken, SC, 2018.

10. Hunter, S. C.; Woodham, W. H. *Evaluation of Thermolytic Hydrogen Generation Rate Models at High-Temperature/High-Hydroxide Regimes*; SRNL-STI-2020-00274, Revision 0; Savannah River National Laboratory Aiken, SC, 2020.

Appendix A.

Safety Data Sheet for Mobil SHC 630
Accessed Online on 18-January-2021 at
https://www.mobil.com/en/lubricants/for-businesses/industrial/lubricants/products/products/mobil-shc-630

SAFETY DATA SHEET

SECTION 1 PRODUCT AND COMPANY IDENTIFICATION

PRODUCT

Product Name: **MOBIL SHC 630**
Product Description: Synthetic Base Stocks and Additives
Product Code: 201560500550, 602953-00, 970782
Intended Use: Circulating/gear oil

COMPANY IDENTIFICATION

Supplier: **EXXON MOBIL CORPORATION**
22777 Springwoods Village Parkway
Spring, TX 77389 USA

24 Hour Health Emergency	609-737-4411
Transportation Emergency Phone	800-424-9300 or 703-527-3887 CHEMTREC
Product Technical Information	800-662-4525
MSDS Internet Address	www.exxon.com, www.mobil.com

SECTION 2 HAZARDS IDENTIFICATION

This material is not hazardous according to regulatory guidelines (see (M)SDS Section 15).

Other hazard information:

HAZARD NOT OTHERWISE CLASSIFIED (HNOC): None as defined under 29 CFR 1910.1200.

PHYSICAL / CHEMICAL HAZARDS

No significant hazards.

HEALTH HAZARDS

High-pressure injection under skin may cause serious damage. Excessive exposure may result in eye, skin, or respiratory irritation.

ENVIRONMENTAL HAZARDS

No significant hazards.

NFPA Hazard ID:	Health:	0	Flammability:	1	Reactivity:	0
HMIS Hazard ID:	Health:	0	Flammability:	1	Reactivity:	0

NOTE: This material should not be used for any other purpose than the intended use in Section 1 without expert advice. Health studies have shown that chemical exposure may cause potential human health risks which may vary from person to person.

SECTION 3 COMPOSITION / INFORMATION ON INGREDIENTS

This material is defined as a mixture.

Hazardous Substance(s) or Complex Substance(s) required for disclosure

Name	CAS#	Concentration*	GHS Hazard Codes
1-DECENE, HOMOPOLYMER HYDROGENATED	68037-01-4	20 - < 30%	H304
PHOSPHORIC ACID, METHYLPHENYL DIPHENYL ESTER	26444-49-5	0.1 - < 0.25%	H400(M factor 1), H410(M factor 1)
TRIPHENYL PHOSPHATE	115-86-6	0.1 - < 0.25%	H400(M factor 1), H411

* All concentrations are percent by weight unless material is a gas. Gas concentrations are in percent by volume.

As per paragraph (i) of 29 CFR 1910.1200, formulation is considered a trade secret and specific chemical identity and exact percentage (concentration) of composition may have been withheld. Specific chemical identity and exact percentage composition will be provided to health professionals, employees, or designated representatives in accordance with applicable provisions of paragraph (i).

SECTION 4 FIRST AID MEASURES

INHALATION

Remove from further exposure. For those providing assistance, avoid exposure to yourself or others. Use adequate respiratory protection. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical assistance. If breathing has stopped, assist ventilation with a mechanical device or use mouth-to-mouth resuscitation.

SKIN CONTACT

Wash contact areas with soap and water. If product is injected into or under the skin, or into any part of the body, regardless of the appearance of the wound or its size, the individual should be evaluated immediately by a physician as a surgical emergency. Even though initial symptoms from high pressure injection may be minimal or absent, early surgical treatment within the first few hours may significantly reduce the ultimate extent of injury.

EYE CONTACT

Flush thoroughly with water. If irritation occurs, get medical assistance.

INGESTION

First aid is normally not required. Seek medical attention if discomfort occurs.

SECTION 5 FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA

Appropriate Extinguishing Media: Use water fog, foam, dry chemical or carbon dioxide (CO2) to extinguish flames.

Inappropriate Extinguishing Media: Straight Streams of Water

FIRE FIGHTING

Fire Fighting Instructions: Evacuate area. Prevent runoff from fire control or dilution from entering streams, sewers, or drinking water supply. Firefighters should use standard protective equipment and in enclosed spaces, self-contained breathing apparatus (SCBA). Use water spray to cool fire exposed surfaces and to protect personnel.

Hazardous Combustion Products: Aldehydes, Incomplete combustion products, Oxides of carbon, Smoke, Fume, Sulfur oxides

FLAMMABILITY PROPERTIES

Flash Point [Method]: >210°C (410°F) [ASTM D-92]
Flammable Limits (Approximate volume % in air): LEL: 0.9 UEL: 7.0
Autoignition Temperature: N/D

SECTION 6 ACCIDENTAL RELEASE MEASURES

NOTIFICATION PROCEDURES

In the event of a spill or accidental release, notify relevant authorities in accordance with all applicable regulations. US regulations require reporting releases of this material to the environment which exceed the applicable reportable quantity or oil spills which could reach any waterway including intermittent dry creeks. The National Response Center can be reached at (800)424-8802.

PROTECTIVE MEASURES

Avoid contact with spilled material. See Section 5 for fire fighting information. See the Hazard Identification Section for Significant Hazards. See Section 4 for First Aid Advice. See Section 8 for advice on the minimum requirements for personal protective equipment. Additional protective measures may be necessary, depending on the specific circumstances and/or the expert judgment of the emergency responders.

SPILL MANAGEMENT

Land Spill: Stop leak if you can do it without risk. Recover by pumping or with suitable absorbent.

Water Spill: Stop leak if you can do it without risk. Confine the spill immediately with booms. Warn other shipping. Remove from the surface by skimming or with suitable absorbents. Seek the advice of a specialist before using dispersants.

Water spill and land spill recommendations are based on the most likely spill scenario for this material; however, geographic conditions, wind, temperature, (and in the case of a water spill) wave and current direction and speed may greatly influence the appropriate action to be taken. For this reason, local experts should be consulted. Note: Local regulations may prescribe or limit action to be taken.

ENVIRONMENTAL PRECAUTIONS

Large Spills: Dike far ahead of liquid spill for later recovery and disposal. Prevent entry into waterways, sewers, basements or confined areas.

SECTION 7 HANDLING AND STORAGE

HANDLING

Prevent small spills and leakage to avoid slip hazard. Material can accumulate static charges which may cause an electrical spark (ignition source). When the material is handled in bulk, an electrical spark could ignite any flammable vapors from liquids or residues that may be present (e.g., during switch-loading operations). Use proper bonding and/or ground procedures. However, bonding and grounds may not eliminate the hazard from static accumulation. Consult local applicable standards for guidance. Additional references include American Petroleum Institute 2003 (Protection Against Ignitions Arising out of Static, Lightning and Stray Currents) or National Fire Protection Agency 77 (Recommended Practice on Static Electricity) or CENELEC CLC/TR 50404 (Electrostatics - Code of practice for the avoidance of hazards due to static electricity).

Static Accumulator: This material is a static accumulator.

STORAGE

The type of container used to store the material may affect static accumulation and dissipation. Do not store in open or unlabelled containers.

SECTION 8 EXPOSURE CONTROLS / PERSONAL PROTECTION

EXPOSURE LIMIT VALUES

Exposure limits/standards (Note: Exposure limits are not additive)

Substance Name	Form	Limit / Standard			NOTE	Source
1-DECENE, HOMOPOLYMER HYDROGENATED	Aerosols (thoracic fraction)	TWA	5 mg/m3		N/A	ExxonMobil
TRIPHENYL PHOSPHATE		TWA	3 mg/m3		N/A	OSHA Z1
TRIPHENYL PHOSPHATE		TWA	3 mg/m3		N/A	ACGIH

Exposure limits/standards for materials that can be formed when handling this product: When mists/aerosols can occur the following are recommended: 5 mg/m³ - ACGIH TLV (inhalable fraction), 5 mg/m³ - OSHA PEL.

NOTE: Limits/standards shown for guidance only. Follow applicable regulations.

No biological limits allocated.

ENGINEERING CONTROLS

The level of protection and types of controls necessary will vary depending upon potential exposure conditions. Control measures to consider:

No special requirements under ordinary conditions of use and with adequate ventilation.

PERSONAL PROTECTION

Personal protective equipment selections vary based on potential exposure conditions such as applications, handling practices, concentration and ventilation. Information on the selection of protective equipment for use with this material, as provided below, is based upon intended, normal usage.

Respiratory Protection: If engineering controls do not maintain airborne contaminant concentrations at a level which is adequate to protect worker health, an approved respirator may be appropriate. Respirator selection, use, and maintenance must be in accordance with regulatory requirements, if applicable. Types of respirators to be considered for this material include:

No special requirements under ordinary conditions of use and with adequate ventilation.

For high airborne concentrations, use an approved supplied-air respirator, operated in positive pressure mode. Supplied air respirators with an escape bottle may be appropriate when oxygen levels are inadequate, gas/vapor warning properties are poor, or if air purifying filter capacity/rating may be exceeded.

Hand Protection: Any specific glove information provided is based on published literature and glove manufacturer data. Glove suitability and breakthrough time will differ depending on the specific use conditions. Contact the glove manufacturer for specific advice on glove selection and breakthrough times for your use conditions. Inspect and replace worn or damaged gloves. The types of gloves to be considered for this material include:

No protection is ordinarily required under normal conditions of use.

Eye Protection: If contact is likely, safety glasses with side shields are recommended.

Skin and Body Protection: Any specific clothing information provided is based on published literature or manufacturer data. The types of clothing to be considered for this material include:

No skin protection is ordinarily required under normal conditions of use. In accordance with good industrial hygiene practices, precautions should be taken to avoid skin contact.

Specific Hygiene Measures: Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants. Discard contaminated clothing and footwear that cannot be cleaned. Practice good housekeeping.

ENVIRONMENTAL CONTROLS

Comply with applicable environmental regulations limiting discharge to air, water and soil. Protect the environment by applying appropriate control measures to prevent or limit emissions.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Note: Physical and chemical properties are provided for safety, health and environmental considerations only and may not fully represent product specifications. Contact the Supplier for additional information.

GENERAL INFORMATION

Physical State: Liquid
Color: Orange
Odor: Characteristic
Odor Threshold: N/D

IMPORTANT HEALTH, SAFETY, AND ENVIRONMENTAL INFORMATION

Relative Density (at 15 °C): 0.854
Flammability (Solid, Gas): N/A
Flash Point [Method]: >210°C (410°F) [ASTM D-92]

Flammable Limits (Approximate volume % in air): LEL: 0.9 UEL: 7.0
Autoignition Temperature: N/D
Boiling Point / Range: > 316°C (600°F)
Decomposition Temperature: N/D
Vapor Density (Air = 1): > 2 at 101 kPa
Vapor Pressure: < 0.013 kPa (0.1 mm Hg) at 20 °C
Evaporation Rate (n-butyl acetate = 1): N/D
pH: N/A
Log Pow (n-Octanol/Water Partition Coefficient): > 3.5
Solubility in Water: Negligible
Viscosity: 220 cSt (220 mm2/sec) at 40 °C | 28.5 cSt (28.5 mm2/sec) at 100°C
Oxidizing Properties: See Hazards Identification Section.

OTHER INFORMATION

Freezing Point: N/D
Melting Point: N/A
Pour Point: -36°C (-33°F)

SECTION 10 STABILITY AND REACTIVITY

REACTIVITY: See sub-sections below.

STABILITY: Material is stable under normal conditions.

CONDITIONS TO AVOID: Excessive heat. High energy sources of ignition.

MATERIALS TO AVOID: Strong oxidizers

HAZARDOUS DECOMPOSITION PRODUCTS: Material does not decompose at ambient temperatures.

POSSIBILITY OF HAZARDOUS REACTIONS: Hazardous polymerization will not occur.

SECTION 11 TOXICOLOGICAL INFORMATION

INFORMATION ON TOXICOLOGICAL EFFECTS

Hazard Class	Conclusion / Remarks
Inhalation	
Acute Toxicity: No end point data for material.	Minimally Toxic. Based on assessment of the components.
Irritation: No end point data for material.	Negligible hazard at ambient/normal handling temperatures.
Ingestion	
Acute Toxicity: No end point data for material.	Minimally Toxic. Based on assessment of the components.
Skin	
Acute Toxicity: No end point data for material.	Minimally Toxic. Based on assessment of the components.
Skin Corrosion/Irritation: No end point data for material.	Negligible irritation to skin at ambient temperatures. Based on assessment of the components.
Eye	
Serious Eye Damage/Irritation: No end point	May cause mild, short-lasting discomfort to eyes. Based on

data for material.	assessment of the components.
Sensitization	
Respiratory Sensitization: No end point data for material.	Not expected to be a respiratory sensitizer.
Skin Sensitization: No end point data for material.	Not expected to be a skin sensitizer. Based on assessment of the components.
Aspiration: Data available.	Not expected to be an aspiration hazard. Based on physico-chemical properties of the material.
Germ Cell Mutagenicity: No end point data for material.	Not expected to be a germ cell mutagen. Based on assessment of the components.
Carcinogenicity: No end point data for material.	Not expected to cause cancer. Based on assessment of the components.
Reproductive Toxicity: No end point data for material.	Not expected to be a reproductive toxicant. Based on assessment of the components.
Lactation: No end point data for material.	Not expected to cause harm to breast-fed children.
Specific Target Organ Toxicity (STOT)	
Single Exposure: No end point data for material.	Not expected to cause organ damage from a single exposure.
Repeated Exposure: No end point data for material.	Not expected to cause organ damage from prolonged or repeated exposure. Based on assessment of the components.

OTHER INFORMATION

For the product itself:

Repeated and/or prolonged exposure may cause irritation to the skin, eyes, or respiratory tract.

Contains:

Synthetic base oils: Not expected to cause significant health effects under conditions of normal use, based on laboratory studies with the same or similar materials. Not mutagenic or genotoxic. Not sensitizing in test animals and humans.

The following ingredients are cited on the lists below: None.

--REGULATORY LISTS SEARCHED--

1 = NTP CARC	3 = IARC 1	5 = IARC 2B
2 = NTP SUS	4 = IARC 2A	6 = OSHA CARC

SECTION 12 ECOLOGICAL INFORMATION

The information given is based on data for the material, components of the material, or for similar materials, through the application of bridging principals.

ECOTOXICITY

Material -- Not expected to be harmful to aquatic organisms.
Material -- Not expected to demonstrate chronic toxicity to aquatic organisms.

MOBILITY

SEA (IMDG): Not Regulated for Sea Transport according to IMDG-Code

Marine Pollutant: No

AIR (IATA): Not Regulated for Air Transport

SECTION 15 REGULATORY INFORMATION

OSHA HAZARD COMMUNICATION STANDARD: This material is not considered hazardous in accordance with OSHA HazCom 2012, 29 CFR 1910.1200.

Listed or exempt from listing/notification on the following chemical inventories: AIIC, DSL, IECSC, KECI, TSCA

Special Cases:

Inventory	Status
ENCS	Restrictions Apply

SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302

SARA (311/312) REPORTABLE GHS HAZARD CLASSES: None.

SARA (313) TOXIC RELEASE INVENTORY: This material contains no chemicals subject to the supplier notification requirements of the SARA 313 Toxic Release Program.

The following ingredients are cited on the lists below:

Chemical Name	CAS Number	List Citations
OCTAMETHYLCYCLOTETRASILOXANE	556-67-2	5
SEVERELY HYDROTREATED HEAVY PARAFFINIC DISTILLATE	64742-54-7	19

--REGULATORY LISTS SEARCHED--

1 = ACGIH ALL
2 = ACGIH A1
3 = ACGIH A2
4 = OSHA Z
5 = TSCA 4
6 = TSCA 5a2
7 = TSCA 5e
8 = TSCA 6
9 = TSCA 12b
10 = CA P65 CARC
11 = CA P65 REPRO
12 = CA RTK
13 = IL RTK
14 = LA RTK
15 = MI 293
16 = MN RTK
17 = NJ RTK
18 = PA RTK
19 = RI RTK

Code key: CARC=Carcinogen; REPRO=Reproductive

SECTION 16 OTHER INFORMATION

N/D = Not determined, N/A = Not applicable

KEY TO THE H-CODES CONTAINED IN SECTION 3 OF THIS DOCUMENT (for information only):
H304: May be fatal if swallowed and enters airways; Aspiration, Cat 1
H400: Very toxic to aquatic life; Acute Env Tox, Cat 1
H410: Very toxic to aquatic life with long lasting effects; Chronic Env Tox, Cat 1
H411: Toxic to aquatic life with long lasting effects; Chronic Env Tox, Cat 2

THIS SAFETY DATA SHEET CONTAINS THE FOLLOWING REVISIONS:
Section 15: List Citations Table information was modified.
Section 15: National Chemical Inventory Listing information was modified.

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Internal Use Only
MHC: 0B, 0B, 0, 0, 0, 0 PPEC: A

DGN: 2007966XUS (1027736)

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