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16. Abstract

Cabin air quality within commercial aircraft has persisted as an area of concern, specifically with regard to potential exposures of and health impacts to flight crew and/or passengers. Many efforts have focused on understanding quality of the air within aircraft and the potential risks of exposure to chemicals within cabin or engine bleed air; however, variability in collection and analytical methods, and samples themselves, in addition to the lack of validated sensors for accurate in-cabin measurements have left many questions unanswered.

This study was designed to assess engine bleed air for chemical contaminants following engine fluid contamination events and evaluate the potential risks for health-related effects should human exposure occur at the reported concentrations. Contamination events were simulated by injecting a variety of aircraft fluids, including oils, hydraulic fluids and a deicing fluid into an engine (for off aircraft engine stand tests) or a propulsion engine or APU (for ground-based on aircraft tests). A vast variety of chemical compounds were identified across the study, including volatile organic compounds, carbonyls and organophosphates. Interestingly, despite the study simulating contamination events by actively injecting aircraft fluids, the chemical compounds, while many, were identified at relatively low concentrations – on the order of parts per billion (ppb) or less – with none reaching the level of parts per million (ppm) where many exposure recommendations, limits and guidelines would start to restrict exposure in an effort to prevent the risk of potential health effects.

Only two compounds were found to have exceeded health exposure recommendations, limits, values and/or guidelines. Tridecane, a potential dermal irritant, was found at a very low concentration (14.86 ppb). This value exceeded tridecane's only established guideline, although the justification for the extremely low guideline could not be scientifically validated. The other compound that was found in concentrations that exceeded one exposure recommendation was formaldehyde; however, those formaldehyde concentrations (reaching ~100 ppb) did not exceed established/accepted exposure limits and guidelines, and likely present little to no health risk at concentrations ~100 ppb.

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Technical Report

Toxicological Evaluation of Chemical Compounds Identified in Air Samples Collected from Simulated Engine and Aircraft Contamination Events

Report prepared for:
Federal Aviation Administration Civil Aerospace Medical Institute (FAA/CAMI)

Report prepared by:

Karen L. Mumy, PhD, DABT
Director, Environmental Health Effects
Naval Medical Research Unit Dayton

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EXECUTIVE SUMMARY

Cabin air quality within commercial aircraft has persisted as an area of concern, specifically with regard to potential exposures of and health impacts to flight crew and/or passengers. Many efforts have focused on understanding quality of the air within aircraft and the potential risks of exposure to chemicals within cabin or engine bleed air; however, variability in collection and analytical methods, and samples themselves, in addition to the lack of validated sensors for accurate in-cabin measurements have left many questions unanswered.

This study was designed to assess engine bleed air for chemical contaminants following engine fluid contamination events and evaluate the potential risks for health-related effects should human exposure occur at the reported concentrations. Contamination events were simulated by injecting a variety of aircraft fluids, including oils, hydraulic fluids and a deicing fluid into an engine (for off aircraft engine stand tests) or a propulsion engine or APU (for ground-based on aircraft tests). A vast variety of chemical compounds were identified across the study, including volatile organic compounds, carbonyls and organophosphates. Interestingly, despite the study simulating contamination events by actively injecting aircraft fluids, the chemical compounds, while many, were identified at relatively low concentrations – on the order of parts per billion (ppb) or less – with none reaching the level of parts per million (ppm) where many exposure recommendations, limits and guidelines would start to restrict exposure in an effort to prevent the risk of potential health effects.

Only two compounds were found to have exceeded health exposure recommendations, limits, values and/or guidelines. Tridecane, a potential dermal irritant, was found at a very low concentration (14.86 ppb). This value exceeded tridecane's only established guideline, although the justification for the extremely low guideline could not be scientifically validated. The other compound that was found in concentrations that exceeded one exposure recommendation was formaldehyde; however, those formaldehyde concentrations (reaching ~100 ppb) did not exceed established/accepted exposure limits and guidelines, and likely present little to no health risk at concentrations ~100 ppb.

BACKGROUND

Cabin air quality within commercial aircraft has persisted as an area of concern, specifically with regard to potential exposures of and health impacts to flight crew and/or passengers. Many efforts have focused on understanding quality of the air within aircraft and the potential risks of exposure to chemicals within cabin or engine bleed air (e.g., Chaturvedi 2011; Chen et al., 2021; Hayes et al., 2021); however, variability in collection and analytical methods, and samples themselves, in addition to the lack of validated sensors for accurate in-cabin measurements have left many questions unanswered.

Part c of Section 326 of the Federal Aviation Administration (FAA) Reauthorization Act of 2018 stated that the FAA was to "research to develop techniques to monitor bleed air quality" with the following specific four tasks to be the focus of further study: "(1) to identify and measure the constituents and levels of constituents resulting from bleed air in the cabins of a representative set of commercial aircraft in operation of the United States; (2) to assess the potential health effects of such constituents on passengers and cabin and flight deck crew; (3) to identify technologies suitable to provide reliable and accurate warning of bleed air contamination, including technologies to effectively monitor the aircraft air supply system when the aircraft is in flight; and (4) to identify potential techniques to prevent fume events."

In response to the direction by Congress, FAA Civil Aerospace Medical Institute (CAMI) initiated a multi-year airplane cabin air quality study to research the impact of contaminated air events onboard commercial aircraft. To address Tasks 1 and 2 above, a study was designed to assess engine bleed air for chemical contaminants following engine fluid contamination events and examine the potential for health-related risks of human exposure to chemicals generated during (simulated) contaminated air incidents. The Naval Medical Research Unit Dayton was requested to provide toxicological expertise to evaluate the chemical compounds, and levels thereof, identified through various methods and testing. Specifically, this report addresses whether the identified chemical compounds, at the concentrations reported, exceed any of six different health exposure recommendations, limits, values or guidelines considered.

APPROACH – SAMPLE COLLECTION AND ANALYSES

To identify and quantify potential chemical contaminants in aircraft engine bleed air, a series of engine stand and ground-based on aircraft (Boeing 747) tests were performed in May 2022 and May 2023, respectively. In each test, different commercial aircraft fluids were separately injected into an engine system. Different sampling media were used to collect air samples, and the media were analyzed by appropriate methods for identification and quantification of organophosphates, polycyclic aromatic hydrocarbons, volatile organic compounds (VOCs) and carbonyls.

Please see any conjunctive reports by Kansas State University and the Naval Air Warfare Center Aircraft Division for details with regard to injection events, sampling and chemical analyses, as those specifics are not included here given that this report is meant to focus on the toxicological evaluation. The general schemes for the injection events and sampling are briefly described below.

Engine Stand Tests

To identify potential chemical contaminants in aircraft engine bleed air, a series of engine stand tests were performed in May 2022 at Kansas State University where each of six different commercial aircraft fluids were separately injected into an engine system. The six different fluids were Eastman Turbo Oil 2389 (standard oil), Mobil Jet Oil II (standard oil), Mobil Jet Oil 387 (high thermal stability oil), HyJet IV-A Plus (hydraulic fluid), Skydrol PE-5 (hydraulic fluid), and Safewing MP/LFD 88 Dilute (deicing fluid).

Baseline samples (at 200°C) were collected prior to the introduction of the fluid into the engine. Fluids were injected individually at an injection site. Following injection, samples were collected at two locations – the inlet line and downstream at the bleed air line – and at two bleed air temperatures - 200°C and ~250-260°C. Samples were collected using different sampling media to capture and analyze different types of compounds. The samples were transferred to respective laboratories for appropriate analyses. Chemical analyses of samples were performed by both the RJ Lee Group, Inc. and the Naval Air Warfare Center Aircraft Division, with the latter being limited to analyses for VOCs.

Ground-Based On Aircraft Tests

The ground-based on aircraft tests were carried out on a Boeing 747 aircraft at the FAA William J. Hughes Technical Center (Atlantic City, NJ) with the intent of simulating fluid leaks on an airplane's Environmental Control System (ECS) by injecting aircraft fluids into either a propulsion engine (specifically Engine #3) or an Auxiliary Power Unit (APU). Tests took place in May of 2023.

The ground-based on aircraft tests involved injecting specific amounts of commercial aircraft fluids into the aircraft's ECS via either the propulsion engine or APU to simulate contamination events under different operating conditions. The different aircraft fluids were Mobil Jet Oil II (standard oil), Eastman Turbo Oil 2197 (high thermal stability oil), and Skydrol PE-5 (hydraulic fluid). The bleed air was sampled using different media at various locations at temperatures up to 315°C (“climb mode” operating condition).

The samples were transferred to respective laboratories for appropriate analyses. The media were then chemically analyzed to characterize the chemical composition of the individual samples. Chemical analyses of samples were performed by both the RJ Lee Group, Inc. and the Naval Air Warfare Center Aircraft Division, with the latter being limited to analyses for VOCs.

APPROACH – TOXICOLOGICAL CONSIDERATIONS

“All things are poison, and nothing is without poison; the dosage alone makes it so a thing is not a poison.” — Paracelsus, 1538

Exposures to chemical compounds have the potential to result in a vast array of health effects – from mild irritation to headaches, or to severe or debilitating or permanent effects. However, whether a particular health effect is likely to occur is dependent on not only the chemical compound in question, but also the extent (amount) and duration of exposure. The basic tenet of toxicology is that “the dose makes the poison”. That is to say that exposure to even the most toxic compounds can result in no adverse effect as long as they are present at an appropriately low level. This basic principle makes it possible to delineate exposure standards in the form of “exposure limits” and “guidelines” that serve as critical tools in risk assessments involving exposure to various chemicals. Exposure limits and guidelines define specific amounts/concentrations for a given chemical that would be considered safe if exposed to that amount/concentration over a given period of time. These limits or guidelines are typically developed for work environments and workshifts, but can be extrapolated for other uses, when appropriate. Further, it is generally regarded that limiting exposure to amounts/concentrations at or less than those described by an exposure limit/guideline, or for less than the time defined, would be considered safe. In other words, exposures at or below the exposure limit for the period of time (or less) defined by the limit should largely protect an individual from the adverse health effects that may otherwise be associated with exposure to a particular chemical compound at a higher concentration or longer period of time. That said, unfortunately, not every substance has a defined or published exposure limit or guideline available and not every substance for which a limit or guideline exists has a full complement of limits and guidelines.

Exposure limits and guidelines are generated by agencies or organizations knowledgeable in the fields of toxicology and risk assessment. These groups include the National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), American Conference of Governmental Industrial Hygienists (ACGIH), Environmental Protection Agency (EPA), American Industrial Hygiene Association (AIHA), Occupational Alliance for Risk Science (OARS) and Department of Energy (DOE) Subcommittee on Consequence Assessment and Protective Actions (SCAPA). When evaluating the risk of potential health effects associated with the chemical compounds identified and quantified in FAA/CAMI’s study, the below types of exposure limits and guidelines were considered, when available (not all, if any, are available for a given substance).

Of note, exposure limits and guidelines are typically reported as parts per million (ppm), where 1 ppm = 1,000 parts per billion (ppb). This is pertinent to emphasize given that the concentrations reported in this study are given in ppb units.

NIOSH’s Recommended Exposure Limits (RELs)

NIOSH develops Recommended Exposure Limits (RELs) as *recommendations* for occupational exposure limits (OELs) with the intent to protect workers from adverse health effects related to an exposure. NIOSH develops RELs based on data from human and animal research and studies. RELs are not legal standards but are taken into consideration by OSHA for their development of Permissible Exposure Limits (PELs) which are legally enforceable standards.

RELs are developed as a time-weighted average (TWA) concentration for exposure to a chemical compound that is recommended as a safe exposure level. It is calculated as an average exposure over a

period of up to 10 hours over a 40-hour workweek. NIOSH may also *recommend* a Short-Term Exposure Limit (STEL) describing a concentration that is not to be exceeded during a 15-minute period. Additionally, a “Ceiling” REL, when applicable, is a concentration that should not be exceeded at any time.

It is important to note that while NIOSH RELs help to inform OSHA PELs, the two do not always match. In fact, NIOSH RELs may be more conservative (i.e., recommending a lower concentration) compared to OSHA’s published PELs.

OSHA’s Permissible Exposure Limits (PELs)

OSHA sets Permissible Exposure Limits (PELs) for hazardous substances as regulatory limits that are legally enforceable standards. PELs define the safe level of a substance by assessing exposure and adverse outcome data from both animal bioassays and human studies. OSHA PELs are based on an 8-hour TWA exposure (vs. NIOSH’s 10-hour TWA) over a 40-hour workweek. Similar to NIOSH’s recommended STEL, OSHA may also set a STEL for an exposure period of 15-minutes (unless otherwise noted). OSHA may also provide a “Ceiling” concentration that is not to be exceeded during any part of the workday.

ACGIH’s Threshold Limit Values (TLVs®)

ACGIH determines Threshold Limit Values (TLVs®) that are defined by the ACGIH as “health-based values established by committees that review existing published and peer-reviewed literature in various scientific disciplines (e.g., industrial hygiene, toxicology, occupational medicine, and epidemiology)”. TLVs® are considered as guidelines, not regulatory standards. TLVs® describe airborne concentrations of chemical compounds that nearly all workers may be repeatedly exposed to (“day after day, over a working lifetime”) without experiencing adverse health effects. Specifically, a TLV®-TWA describes the exposures for a traditional 8-hour workday and a 40-hour workweek.

As with NIOSH and OSHA, ACGIH also considers a STEL for a 15-minute TWA exposure not to be exceeded at any point during the workday, regardless of the 8-hour TWA being within the TLV®–TWA. According to ACGIH “the TLV®–STEL is the concentration to which it is believed that nearly all workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, 3) dose-rate-dependent toxic effects, or 4) narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self-rescue, or materially reduced work efficiency”.

EPA’s Acute Exposure Guidelines (AEGLs)

The EPA calculates Acute Exposure Guidelines (AEGLs) that describe concentrations of airborne chemicals at which health effects *may* occur in the general public, to include the elderly, children and susceptible individuals. AEGLs are categorized into three different levels (1, 2 and 3), according to the severity of effects that are predicted to occur in the general population at levels *above* the defined exposure concentration(s).

- Below AEGL-1: Airborne concentrations that are below the AEGL-1 describe exposures that may result in mild and transient, but “progressively increasing”, and non-disabling odor, taste, and sensory irritation and/or other asymptomatic, non-sensory effects.

- Level 1 (AEGL-1): Exposure above this level (i.e., concentration) to a chemical compound or substance is predicted to potentially result in “notable discomfort, irritation, or certain asymptomatic non-sensory effects” (per the EPA). These effects are not to be disabling and would be transient in nature and reversible when the exposure ceases.

- Level 2 (AEGL-2): Exposure above this level (i.e., concentration) to a chemical compound or substance is predicted to potentially result in “irreversible or other serious, long-lasting adverse

health effects or an impaired ability to escape" (per the EPA). Exposure concentrations described for an AEGL-2 would inherently be higher than for an AEGL-1.

- Level 3 (AEGL-3): Exposure above this level (i.e., concentration) to a chemical compound or substance is predicted to potentially result in "life-threatening health effects or death" (per the EPA). Exposure concentrations described for an AEGL-3 would inherently be higher than for an AEGL-1 or an AEGL-2.

For each level of severity, guidelines are calculated for five non-repeated exposure periods that include 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours. For the purpose of this FAA/CAMI evaluation, only AEGL-1 values were considered and for an 8-hour period of time. These values encompass the most conservative level of exposure over the longest duration as a worst-case scenario.

AIHA's and OARS's Workplace Environmental Exposure Levels (WEELs)

AIHA and OARS, a volunteer group of toxicologists, define Workplace Environmental Exposure Levels (WEELs) as health-based guide values for chemicals. The WEELs intend to describe the airborne concentrations of a chemical that would protect the majority of workers from adverse health effects associated with an occupational chemical exposure at a given concentration. WEELs are defined for an 8-hour TWA exposure.

For the purpose of this FAA/CAMI evaluation, WEELs were generally only considered when other limits, values and guidelines were not available.

DOE/SCAPA's Protective Action Criteria (PACs)

The DOE's SCAPA derives Protective Action Criteria (PACs) as a means of knowing when/how to plan and respond to "uncontrolled releases" of hazardous chemicals. Similar to EPA's AEGLs, there are three levels of PAC values (1, 2 and 3) in which each value is associated with an increase in severity of effect from a higher level (i.e., concentration) of exposure. PAC-1, 2 and 3 values are most often based on the EPA's AEGL's themselves (see above) for the 1 hour AEGL value, and the various PAC values correlate to the severity of health effects, as described below:

- Level 1 (PAC-1): Mild, transient health effects.
- Level 2 (PAC-2): Irreversible or other serious health effects that could impair the ability to take protective action.
- Level 3 (PAC-3): Life-threatening health effects.

Given that PAC values are primarily for uncontrolled and unplanned releases, such as in the cases of accidents or disasters, PACs were rarely considered for the purpose of this FAA/CAMI evaluation. They were only considered when other limits, values and guidelines (including AEGLs) were not otherwise available.

EVALUATION OF COMPOUNDS WITH REGARD TO EXPOSURE LIMITS/GUIDELINES

The purpose of this report is to outline whether the identified chemical compounds, at the concentrations described, exceed health exposure limits or guidelines. A series of 21 tables describe the chemical compounds identified at different sample locations and under different conditions, their concentrations, appropriate exposure limits or guidelines for that chemical (if available) and whether or not (Y/N) any of the reported concentrations exceed a specific recommendation, limit or guideline. Tables are per aircraft fluid and represent either Engine Stand Tests or On-Aircraft tests. Instances where a chemical compound is listed more than once within the same table indicates that the chemical was

identified in more than one type of analyses (i.e., for organophosphates, polycyclic aromatic hydrocarbons, VOCs and carbonyls) or was tentatively identified more than once under a different retention time.

Chemicals Identified in Engine Stand Tests

Engine stand (off-aircraft) tests were performed with six different fluids were Eastman Turbo Oil 2389 (standard oil), Mobil Jet Oil II (standard oil), Mobil Jet Oil 387 (high thermal stability oil), Skydrol PE-5 (hydraulic fluid), HyJet IV-A Plus (hydraulic fluid), and Safewing MP/LFD 88 Dilute (deicing fluid). The following tables (Tables 1-12) describe the chemical compounds identified and their concentrations, exposure limits/guidelines and whether or not (Y/N) the concentrations reported exceed a given recommendation, limit or guideline. If a concentration exceeded a given recommendation, limit or guideline, that specific concentration is indicated by an asterisk (*) in the table.

Please note that chemical concentrations are provided in parts per billion by volume (ppbV) whereas exposure limits/guidelines are presented in parts per million (ppm), where 1 ppm is equal to 1,000 ppb.

Table 1: Summary of chemicals and concentrations identified following injection of Eastman Turbo Oil 2389 (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Concentration (ppbV, unless otherwise noted)									
	Controls		Baseline (200°C)		200°C		260°C			
Compound (CAS #)	Shipping Blank	Field Blank	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Exposure Limit/Guideline (GL)	Exceeds Exposure Limit/GL (Y/N)
Triisobutyl phosphate (126-71-06)	NC	65.2	0.0226	0.0281	0.0232	0.0297	0.0236	0.0254	N/A	N/A
Tributyl phosphate (126-73-8)	NC	171	0.127	0.267	0.0642	0.263	0.0569	0.240	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Formaldehyde (50-00-0)	<RL	<RL	3.25	16.9*	3.51	8.25	3.11	24.5*	NIOSH: The recommended airborne exposure limit (REL) is 0.016 ppm averaged over a 10-h workshift, and no more than 0.1 ppm during any 15-min period OSHA: Permissible exposure limit (PEL) is 0.75 ppm averaged over an 8-h workshift, not to exceed 2 ppm during any 15-min period EPA AEGL-1 (interim): 0.90 ppm over 8 h	Y N N
Acetaldehyde (75-07-0)	<RL	<RL	1.34	5.82	1.28	3.41	1.27	13.5	NIOSH: Lowest feasible concentration OSHA: 200 ppm averaged over an 8-h workshift ACGIH: Not to exceed 25 ppm (Ceiling)	-- N N
Acrolein (107-02-8)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	1.16	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 0.3 ppm during any 15-min period OSHA: The PEL is 0.1 ppm averaged over 8 h ACGIH: The recommended airborne exposure limit is 0.1 ppm, not to be exceeded at any time EPA AEGL-1: 0.030 ppm over 8 h	N N N N
Acetone (67-64-1)	0.097 µg/ sample	0.113 µg/ sample	2.71	3.82	2.56	3.46	2.47	5.77	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Propionaldehyde (123-38-6)	<RL	<RL	<RL	1.08	<RL	.964	<RL	3.13	ACGIH: The recommended airborne exposure limit is 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 45 ppm over 8 h	N N
Crotonaldehyde (4170-30-3)	<RL	<RL	0.614	<RL	0.844	<RL	0.992	0.286	NIOSH: Recommended time-weighted average (TWA) of 2 ppm in the air over a 10-h workday. OSHA: The PEL is 2 ppm averaged over an 8-h workshift ACGIH: 0.3 ppm, not to be exceeded at any time	N N N
Methyl ethyl ketone (MEK) & Butyraldehyde (78-93-3) (123-72-8)	<RL	<RL	0.600	1.49	0.537	1.27	0.613	4.95	MEK NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period MEK OSHA: The PEL is 200 ppm averaged over an 8-h workday MEK ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL MEK EPA AEGL-1: 200 ppm over 8 h Butyraldehyde OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N N N N N
Benzaldehyde (100-52-7)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	0.274	OARS WEEL: An 8-h time-weighted average (TWA) of 2 ppm; STEL of 4 ppm over 15-min	N
Valeraldehyde (110-62-3)	0.131 µg/ sample	0.117 µg/ sample	1.05	1.75	0.551	0.151	1.36	4.09	NIOSH: The recommended airborne exposure limit is 50 ppm averaged over a 10-h workshift ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workshift	N N
m-Tolualdehyde (620-23-5)	<RL	<RL	<RL	<RL	0.199	<RL	0.058	0.105	N/A	N/A
Hexaldehyde (66-25-1)	<RL	<RL	<RL	0.594	<RL	<RL	<RL	2.34	N/A	N/A
Chloromethane (74-87-3)	NC	NC	<RL	<RL	<RL	1.08	1.00	<RL	OSHA: PEL is 100 ppm over 8 h time-weighted average ACGIH: 50 ppm TWA over 8 h	N N
Methanol (67-56-1)	NC	NC	9.50	<RL	9.87	<RL	8.91	10.2	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 250 ppm as STEL during any 15-min period OSHA: The PEL is 200 ppm averaged over an 8-hour workday ACGIH: 200 ppm as an 8-h TLV®-TWA exposure, and 250 ppm as a STEL (with a skin notation) EPA AEGL-1 (interim): 270 ppm over 8 h	N N N N
Acetone (67-64-1)	NC	NC	<RL	3.08	3.83	3.48	9.39	5.19	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the STEL is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
2-Propanol (67-63-0)	NC	NC	<RL	<RL	<RL	<RL	<RL	53.3	NIOSH: The REL is 400 ppm averaged over a 10-h workshift, not to exceed 500 ppm during any 15-min work period	N

									OSHA: The PEL is 400 ppm averaged over an 8-h workshift ACGIH: The recommended airborne exposure limit is 200 ppm averaged over an 8-h work shift, and 400 ppm as a STEL	N N
m & p-xylene (108-88-3) (106-42-3)	NC	NC	<RL	<RL	<RL	<RL	1.91	<RL	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
o-xylene (95-47-6)	NC	NC	<RL	<RL	<RL	<RL	1.00	<RL	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
4-Ethyltoluene (622-96-8)	NC	NC	<RL	<RL	<RL	<RL	0.88	<RL	DOE/SCAPA PAC-1: 3.1 ppm	N
1,2,4-Trimethylbenzene (95-63-6)	NC	NC	<RL	<RL	<RL	<RL	1.56	<RL	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N
Methyl ethyl ketone (78-93-3)	<RL	<RL	<RL	0.381	<RL	<RL	0.148	0.400	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Tetrahydrofuran (109-99-9)	<RL	<RL	<RL	<RL	0.175	<RL	0.366	<RL	NIOSH: The REL is 200 ppm averaged over a 10-h workday and 250 ppm as a STEL OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workday and 100 ppm as a STEL	N N N
Cyclohexane (110-82-7)	<RL	<RL	0.162	<RL	<RL	<RL	0.164	<RL	NIOSH: The REL is 300 ppm averaged over a 10-h workshift OSHA: The PEL is 300 averaged over an 8-h workshift ACGIH: The threshold limit value (TLV®-TWA) is 100 ppm averaged over an 8-h workshift	N N N
Heptane (142-82-5)	<RL	<RL	0.131	<RL	<RL	<RL	0.143	<RL	NIOSH: The recommended airborne exposure limit is 85 ppm averaged over a 10-h workshift, not to exceed 440 ppm during any 15-min work period	N
Toluene (108-88-3)	<RL	1.96	0.629	0.303	0.205	0.263	0.523	0.188	NIOSH: The REL is 100 ppm as a TWA over 10 h OSHA: The PEL is 200 ppm averaged over an 8-h workshift EPA AEGL-1: 67 ppm over 8 h	N N N
2-Hexanone (591-78-6)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	0.379	NIOSH: The REL is 1 ppm as a TWA over 10 h OSHA: The PEL is 100 ppm averaged over an 8-h workshift	N N
Chlorobenzene (108-90-7)	<RL	0.530	<RL	<RL	<RL	<RL	<RL	<RL	NIOSH: The REL is 75 ppm averaged over a 10-h workshift OSHA: The PEL is 75 ppm averaged over an 8-h workshift ACGIH: The threshold limit value (TLV®-TWA) is 10 ppm averaged over an 8-h workshift EPA AEGL-1: 10 ppm over 8 h	N N N N
Ethyl Benzene (100-41-4)	<RL	<RL	0.205	<RL	0.223	0.160	0.477	0.260	NIOSH: The REL is 100 ppm averaged over a 10-h workshift, not to be exceed 125 ppm during any 15-min work period OSHA: 100 ppm over an 8-h workday ACGIH: 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 33 ppm over 8 h	N N N N
m & p-Xylene (108-88-3) (106-42-3)	<RL	<RL	0.950	0.738	1.08	0.783	2.31	1.27	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
Nonane (111-84-2)	<RL	<RL	1.79	1.48	2.48	1.92	5.38	3.11	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N
o-Xylene (95-47-6)	<RL	<RL	0.505	0.381	0.575	0.413	1.18	0.631	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
Cumene (98-82-8)	<RL	<RL	<RL	<RL	<RL	<RL	0.241	<RL	NIOSH: The REL is 50 ppm averaged over a 10-h workday OSHA: The PEL is 50 ppm averaged over an 8-h workday ACGIH: The TLV®-TWA is 50 ppm averaged over an 8-h workday EPA AEGL-1 (interim): 50 ppm over 8 h	N N N N
n-Propylbenzene (103-65-1)	<RL	<RL	0.193	0.169	0.236	0.195	0.439	0.257	DOE/SCAPA PAC-1: 3.7 ppm	N
4-Ethyltoluene (622-96-8)	<RL	<RL	0.245	0.203	0.239	0.210	0.418	0.257	DOE/SCAPA PAC-1: 3.1 ppm	N
1,3,5-Trimethylbenzene	<RL	<RL	0.350	0.350	0.361	0.345	0.539	0.357	NIOSH: 25 ppm averaged over a 10-h workday	N

(108-67-8)									EPA AEGL-1: 45 ppm over 8 h	N
1,2,4-Trimethylbenzene (95-63-5)	<RL	<RL	1.35	1.43	1.28	1.22	1.55	1.10	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

Per Table 1, among the many compounds identified and quantified from the engine stand test with Eastman Turbo Oil 2389, was formaldehyde (CAS # 50-00-0) that was found at levels that, at face-value, exceeded NIOSH's *recommended* exposure limit (REL). NIOSH's REL recommends an average of 0.016 ppm (16 ppb) over a period of a 10-hour workshift. Formaldehyde was measured at 16.9 ppbV in the bleed air at baseline at 200°C (prior to injection of the fluid) and at 24.5 ppbV in the bleed air at 260°C post-injection. Since formaldehyde was already found and measured during the baseline (pre-injection) collection, its presence or levels cannot entirely be attributed to the oil (i.e., Eastman Turbo Oil 2389).

This finding will be elaborated further within the "Discussion" section.

Table 2: Summary of Tentatively Identified VOCs and concentrations identified following injection of Eastman Turbo Oil 2389 (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)			
Compound (CAS #)	**200°C**	**263°C**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
2-ethylacrolein (922-63-4)	<DL	23.45	N/A	N/A
Benzene (71-43-2)	<DL	2.30	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 1 ppm in a 15-min work period OSHA: Time-weighted average (TWA) is 1 ppm for an 8-h workday, STEL is 5 ppm for any 15-min period ACGIH: The TLV®-TWA is 0.5 ppm averaged over an 8-h workshift and 2.5 ppm as a STEL EPA AEGL-1 (interim): 9 ppm over 8 h	N N N N
Pentanal (110-62-3)	<DL	5.79	N/A	N/A
Hexanal (66-25-1)	2.10	6.37	DOE/SCAPA PAC-1: 1.3 ppm	N
Pentanoic acid (109-52-4)	<DL	9.76	DOE/SCAPA PAC-1 for n-Pentanoic acid is 3.6 ppm	N
p-xylene (106-42-3)	<DL	2.53	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8-h	N N N N
Heptanal (111-71-7)	0.37	9.67	N/A	N/A
Nonane (111-84-2)	0.35	6.08	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N
2,6-dimethyloctane (2051-30-1)	<DL	4.21	N/A	N/A
1-ethyl-2-methyl-benzene (611-14-3)	0.23	2.44	For Ethyl Benzene:	

			NIOSH: The REL is 100 ppm averaged over a 10-h workshift, not to be exceed 125 ppm during any 15-min work period OSHA: 100 ppm over an 8-h workday ACGIH: 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 33 ppm over 8 h	N N N N
Octanal (124-13-0)	<DL	5.61	DOE/SCAPA PAC-1: 3.2 ppm	N
1,2,3-trimethylbenzene (526-73-8)	1.23	16.42	NIOSH: The recommended airborne exposure limit (REL) is 25 ppm averaged over a 10-h workday OSHA: The PEL is 25 ppm averaged over an 8-h workday ACGIH: The recommended airborne exposure limit is 25 ppm averaged over an 8-h workday	N N N
Decane (124-18-5)	<DL	12.46	DOE/SCAPA PAC-1: 6.6 ppm	N
2,6-dimethylnonane (17302-28-2)	<DL	2.61	N/A	N/A
p-cresol (106-44-5)	<DL	11.79	NIOSH: The REL is 2.3 ppm averaged over a 10-h workday OSHA: The PEL is 5 ppm averaged over an 8-h workshift ACGIH: Recommends an airborne exposure limit of 5 ppm averaged over an 8-h workday	N N N
Heptanoic acid (111-14-8)	<DL	28.43	DOE/SCAPA PAC-1: 3.9 ppm	N
Nonanal (124-19-6)	<DL	5.57	DOE/SCAPA PAC-1: 2.6 ppm	N
Undecane (1120-21-4)	3.37	10.25	DOE/SCAPA PAC-1: 0.37 ppm	N
Octanoic acid (124-07-2)	<DL	25.43	DOE/SCAPA PAC-1: 5.1 ppm	N
p-cymene (99-87-6)	1.20	5.00	DOE/SCAPA PAC-1: 22 ppm	N
4,7-dimethylundecane (17301-32-5)	0.78	0.99	N/A	N/A
Dodecane (112-40-3)	14.75	4.39	DOE/SCAPA PAC-1: 0.12 ppm	N
2,6-dimethylundecane (17301-23-4)	3.84	1.44	N/A	N/A
(1,3-dimethylbutyl)cyclohexane (61142-19-6)	0.64	0.57	N/A	N/A
Tridecane (629-50-5)	1.38	4.77	DOE/SCAPA PAC-1: 0.0073 ppm	N
Tetradecane (629-59-4)	9.17	1.13	DOE/SCAPA PAC-1: 3.1 ppm	N
Pentadecane (629-62-9)	<DL	0.66	DOE/SCAPA PAC-1: 1.3 ppm	N
Hexadecane (544-76-3)	<DL	0.78	DOE/SCAPA PAC-1: 3.8 ppm	N
Tributyl phosphate (126-73-8)	<DL	2.46	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m^3) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Dibutyl phenyl phosphate (2528-36-1)	<DL	0.73	NIOSH: The REL is 1ppm averaged over a 10-h workshift, and a STEL of 2 ppm, not to be exceeded during any 15-min work period	N
o-terphenyl (84.15-1)	<DL	3.31	NIOSH: The recommended airborne exposure limit Ceiling is 0.5 ppm (5 mg/m^3), not be exceeded at any time OSHA: The legal airborne permissible exposure limit Ceiling is 1 ppm (9 mg/m^3), not to be exceeded at any time	N N
p-dicyclohexylbenzene (1087-02-1)	<DL	4.14	N/A	N/A
(1,1'-Bicyclohexyl)-4-ylbenzene (20273-27-2)	<DL	3.54	N/A	N/A

Heptanoic acid, anhydride (626-27-7)	<DL	3.03	N/A	N/A
1-cyclohexyl-4-phenylbenezene (1000401-12-4)	<DL	0.85	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

All the concentrations described in Table 2 are relatively low and none exceeded any recommended value, limit or guideline.

Table 3: Summary of chemicals and concentrations identified following injection of Mobil Jet Oil II (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Concentration (ppbV, unless otherwise noted)									
	Controls		Baseline (200°C)		200°C		260°C			
Compound (CAS #)	Shipping Blank	Field Blank	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Exposure Limit/Guideline (GL)	Exceeds Exposure Limit/GL (Y/N)
Triisobutyl phosphate (126-71-06)	NC	NC	0.0196	0.0232	NC	0.0211	NC	0.0208	N/A	N/A
Tributyl phosphate (126-73-8)	NC	NC	0.0434	0.197	NC	0.147	NC	0.169	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Tri-m-cresyl phosphate (563-04-02)	NC	NC	<RL	<RL	NC	0.107	NC	0.163	N/A	N/A
Tri-p-cresyl phosphate (78-32-0)	NC	NC	<RL	<RL	NC	0.113	NC	0.176	N/A	N/A
Formaldehyde (50-00-0)	<RL	NC	4.69	5.60	3.67	6.59	4.70	20.1*	NIOSH: The recommended airborne exposure limit (REL) is 0.016 ppm averaged over a 10-h workshift, and no more than 0.1 ppm during any 15-min period OSHA: Permissible exposure limit (PEL) is 0.75 ppm averaged over an 8-h workshift, not to exceed 2 ppm during any 15-min period EPA AEGL-1 (interim): 0.90 ppm over 8 h	Y N N
Acetaldehyde (75-07-0)	<RL	NC	1.58	2.50	1.45	4.35	1.84	7.49	NIOSH: Lowest feasible concentration OSHA: 200 ppm averaged over an 8-h workshift ACGIH: Not to exceed 25 ppm (Ceiling)	-- N N
Acrolein (107-02-8)	<RL	NC	<RL	<RL	<RL	<RL	<RL	0.828	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 0.3 ppm during any 15-min period OSHA: The PEL is 0.1 ppm averaged over 8 h ACGIH: The recommended airborne exposure limit is 0.1 ppm, not to be exceeded at any time EPA AEGL-1: 0.030 ppm over 8 h	N N N N
Acetone (67-64-1)	0.097 µg/ sample	NC	3.96	3.50	4.63	3.86	4.85	4.75	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Propionaldehyde (123-38-6)	<RL	NC	0.755	0.898	0.674	2.24	0.739	2.03	ACGIH: The recommended airborne exposure limit is 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 45 ppm over 8 h	N N
Crotonaldehyde (4170-30-3)	<RL	NC	0.557	<RL	0.623	<RL	0.672	<RL	NIOSH: Recommended time-weighted average (TWA) of 2 ppm in the air over a 10-h workday. OSHA: The PEL is 2 ppm averaged over an 8-h workshift ACGIH: 0.3 ppm, not to be exceeded at any time	N N N
Methacrolein (78-85-3)	<RL	NC	<RL	<RL	<RL	<RL	<RL	0.493	DOE/SCAPA PAC-1: 0.20 ppm	N
Methyl ethyl ketone (MEK) & Butyraldehyde (78-93-3) (123-72-8)	<RL	NC	0.929	1.09	1.17	2.12	1.38	2.82	MEK NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period MEK OSHA: The PEL is 200 ppm averaged over an 8-h workday MEK ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL MEK EPA AEGL-1: 200 ppm over 8 h Butyraldehyde OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N N N N N
Valeraldehyde (110-62-3)	0.131 µg/ sample	NC	1.524	15.8	1.33	2.10	2.36	4.21	NIOSH: The recommended airborne exposure limit is 50 ppm averaged over a 10-h workshift ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workshift	N N
m-Tolualdehyde (620-23-5)	<RL	0.520	<RL	<RL	<RL	<RL	<RL	<RL	N/A	N/A
Hexaldehyde (66-25-1)	<RL	NC	0.380	0.372	0.391	0.573	0.420	1.02	N/A	N/A
Propene (115-07-01)	NC	NC	<RL	<RL	2.37	<RL	<RL	<RL	ACGIH: The TLV®-TWA is 500 ppm averaged over an 8-h workshift	N
Chloromethane (74-87-3)	NC	NC	<RL	<RL	<RL	<RL	<RL	0.72	OSHA: PEL is 100 ppm over 8 h time-weighted average ACGIH: 50 ppm over 8 h TWA	N N
Methanol (67-56-1)	NC	NC	15.1	12.3	18.1	15.6	12.7	15.6	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 250 ppm as STEL during any 15-min period OSHA: The PEL is 200 ppm averaged over an 8-hour workday ACGIH: 200 ppm as an 8-h TLV®-TWA exposure, and 250 ppm as a STEL (with a skin notation) EPA AEGL-1 (interim): 270 ppm over 8 h	N N N N
Ethanol (64-17-5)	NC	NC	5.33	<RL	12.9	5.43	36.8	48.9	NIOSH: The REL is 1,000 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift	N N

									ACGIH: Threshold limit value (TLV®-TWA) is 1,000 ppm as a STEL	N
Acetone (67-64-1)	NC	NC	4.70	<RL	11.1	7.28	6.12	6.87	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
2-Propanol (67-63-0)	NC	NC	43.1	<RL	101	<RL	86.8	71.8	NIOSH: The REL is 400 ppm averaged over a 10-h workshift, not to exceed 500 ppm during any 15-min work period OSHA: The PEL is 400 ppm averaged over an 8-h work shift ACGIH: The recommended airborne exposure limit is 200 ppm averaged over an 8-h work shift, and 400 ppm as a STEL	N N N
Methyl ethyl ketone (78-93-3)	NC	NC	<RL	<RL	3.79	<RL	<RL	<RL	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Hexane (110-54-3)	NC	NC	1.67	<RL	<RL	<RL	<RL	<RL	NIOSH: The REL is 50 ppm as a TWA over 10-h OSHA: The PEL is 500 ppm as a TWA over 8 h	N N
Toluene (108-88-3)	NC	NC	<RL	<RL	1.16	<RL	<RL	<RL	NIOSH: The REL is 100 ppm as a TWA over 10 h OSHA: The PEL is 200 ppm averaged over an 8-workshift EPA AEGL-1: 67 ppm over 8 h	N N N
Hexane (110-54-3)	<RL	NC	1.72	0.338	NC	0.593	0.124	0.195	NIOSH: The REL is 50 ppm as a TWA over 10-h OSHA: The PEL is 500 ppm as a TWA over 8 h	N N
Methyl ethyl ketone (78-93-3)	<RL	NC	0.217	0.193	NC	0.540	0.326	0.457	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Tetrahydrofuran (109-99-9)	<RL	NC	0.186	<RL	NC	<RL	<RL	<RL	NIOSH: The REL is 200 ppm averaged over a 10-h workday and 250 ppm as a STEL OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workday and 100 ppm as a STEL	N N N
Benzene (71-43-2)	<RL	NC	2.21	<RL	NC	<RL	<RL	<RL	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 1 ppm in a 15-min work period OSHA: Time-weighted average (TWA) is 1 ppm for an 8-h workday, STEL is 5 ppm for any 15-min period ACGIH: The TLV®-TWA is 0.5 ppm averaged over an 8-h workshift and 2.5 ppm as a STEL EPA AEGL-1 (interim): 9 ppm over 8 h	N N N N
Heptane (142-82-5)	<RL	NC	0.281	<RL	NC	<RL	<RL	<RL	NIOSH: The recommended airborne exposure limit is 85 ppm averaged over a 10-h workshift, not to exceed 440 ppm during any 15-min work period	N
Toluene (108-88-3)	<RL	NC	1.98	0.545	NC	0.375	0.663	0.295	NIOSH: The REL is 100 ppm as a TWA over 10 h OSHA: The PEL is 200 ppm averaged over an 8-workshift EPA AEGL-1: 67 ppm over 8 h	N N N
2-Hexanone (591-78-6)	<RL	NC	<RL	<RL	NC	0.190	<RL	0.214	NIOSH: The REL is 1 ppm as a TWA over 10 h OSHA: The PEL is 100 ppm averaged over an 8-h workshift	N N
Ethyl Benzene (100-41-4)	<RL	NC	0.572	0.195	NC	<RL	0.185	0.116	NIOSH: The REL is 100 ppm averaged over a 10 h workshift, not to be exceed 125 ppm during any 15-min work period OSHA: 100 ppm over an 8-h workday ACGIH: 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 33 ppm over 8 h	N N N N
m & p-xylene (108-88-3) (106-42-3)	<RL	NC	1.71	0.700	NC	0.428	0.678	0.593	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
Nonane (111-84-2)	<RL	NC	0.628	0.610	NC	0.473	0.257	1.44	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N
o-xylene (95-47-6)	<RL	NC	0.594	0.278	NC	0.183	0.274	0.302	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
n-Propylbenzene (103-65-1)	<RL	NC	0.158	<RL	NC	<RL	<RL	0.134	DOE/SCAPA PAC-1: 3.7 ppm	N
4-Ethyltoluene (622-96-8)	<RL	NC	0.222	<RL	NC	<RL	0.113	0.166	DOE/SCAPA PAC-1: 3.1 ppm	N
1,3,5-Trimethylbenzene (108-67-8)	<RL	NC	0.253	0.150	NC	<RL	0.172	0.243	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N

1,2,4-Trimethylbenzene (95-63-6)	<RL	NC	0.889	0.603	NC	0.505	0.750	0.877	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

Per Table 3, the engine stand test with Mobil Jet Oil II yielded a variety of chemical compounds, albeit all in low concentrations that, with the exception of formaldehyde, did not exceed exposure limits or guidelines. Again, similar to the engine stand test performed with Eastman Turbo Oil 2389, formaldehyde (CAS # 50-00-0) was found at a level that, at face-value (20.1 ppbV), exceeded NIOSH's *recommended* exposure limit (REL). NIOSH's REL recommends an average of 0.016 ppm (16 ppb) over a period of a 10-hour workshift. Formaldehyde was also found under baseline conditions at lower concentrations; therefore, the presence of formaldehyde is likely not entirely attributed to the oil (i.e., Mobil Jet Oil II). However, the highest concentration identified was in the bleed air at 260°C post-injection.

This finding will be elaborated further within the "Discussion" section.

Table 4: Summary of Tentatively Identified VOCs and concentrations identified following injection of Mobil Jet Oil II (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)			
Compound (CAS #)	**200°C**	**250°C**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Benzene (71-43-2)	1.95	3.11	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 1 ppm in a 15-min work period OSHA: Time-weighted average (TWA) is 1 ppm for an 8-h workday, STEL is 5 ppm for any 15-min period ACGIH: The TLV®-TWA is 0.5 ppm averaged over an 8-h workshift and 2.5 ppm as a STEL EPA AEGL-1 (interim): 9 ppm over 8 h	N N N N
Pentanal (110-62-3)	3.21	3.08	N/A	N/A
Toluene (108-88-3)	1.10	1.44	NIOSH: The REL is 100 ppm as a TWA over 10-h OSHA: The PEL is 200 ppm averaged over an 8-h workshift EPA AEGL-1: 67 ppm over 8 h	N N N
Hexanal (66-25-1)	3.16	2.65	DOE/SCAPA PAC-1: 1.3 ppm	N
2-methylbutanoic acid (116-53-0)	2.35	4.99	N/A	N/A
Pentanoic acid (109-52-4)	16.50	16.74	DOE/SCAPA PAC-1 for n-Pentanoic acid is 3.6 ppm	N
Heptanal (111-71-7)	0.98	4.52	N/A	N/A
Nonane (111-84-2)	<DL	7.64	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N
2,6-dimethyloctane (2051-30-1)	<DL	3.82	N/A	N/A
1,2,3-trimethylbenzene (526-73-8)	0.79	11.02	NIOSH: The recommended airborne exposure limit (REL) is 25 ppm averaged over a 10-h workday OSHA: The PEL is 25 ppm averaged over an 8-h workday	N N

			ACGIH: The recommended airborne exposure limit is 25 ppm averaged over an 8-h workday	N
Decane (124-18-5)	<DL	6.35	DOE/SCAPA PAC-1: 6.6 ppm	N
p-cresol (106-44-5)	<DL	10.50	NIOSH: The REL is 2.3 ppm averaged over a 10-h workday OSHA: The PEL is 5 ppm averaged over an 8-h workshift ACGIH: Recommends an airborne exposure limit of 5 ppm averaged over an 8-h workday	N N N
Heptanoic acid (111-14-8)	8.32	29.45	DOE/SCAPA PAC-1: 3.9 ppm	N
Undecane (1120-21-4)	1.99	4.84	DOE/SCAPA PAC-1: 0.37 ppm	N
Octanoic acid (124-07-2)	8.63	13.74	DOE/SCAPA PAC-1: 5.1 ppm	N
p-cymene (99-87-6)	1.82	2.30	DOE/SCAPA PAC-1: 22 ppm	N
4,7-dimethylundecane (17301-32-5)	1.42	2.08	N/A	N/A
Dodecane (112-40-3)	9.96	11.66	DOE/SCAPA PAC-1: 0.12 ppm	N
2,6-dimethylundecane (17301-23-4)	3.94	3.56	N/A	N/A
(1,3-dimethylbutyl)cyclohexane (61142-19-6)	3.47	1.45	N/A	N/A
2,6-dimethyloctane (2051-30-1)	6.45	6.08	N/A	N/A
Tridecane (629-50-5)	8.30	14.86*	DOE/SCAPA PAC-1: 0.0073 ppm	Y
3,5-dimethyldodecane (107770-99-0)	<DL	2.27	N/A	N/A
n-decanoic acid (334-48-5)	3.39	6.24	N/A	N/A
Oxalic acid, 6-ethyloct-3-yl isohexyl ester (1000309-34-3)	<DL	2.50	For Oxalic Acid: NIOSH: The REL for oxalic acid is 1 mg/m^3 averaged over a 10-h workshift, not to exceed 2 mg/m^3 during any 15-min work period OSHA: PEL 1 mg/m^3 as a TWA over an 8-h workshift ACGIH: The TLV®-TWA is 1 mg/m^3 for oxalic acid averaged over an 8-h workshift, and a STEL of 2 mg/m^3	N N N
2,6,10-trimethyldodecane (3891-98-3)	1.23	2.67	N/A	N/A
Tetradecane (629-59-4)	2.88	7.77	DOE/SCAPA PAC-1: 3.1 ppm	N
2,6,10,14-tetramethylheptadecane (18344-37-1)	<DL	1.49	N/A	N/A
Pentadecane (629-62-9)	0.10	2.71	DOE/SCAPA PAC-1: 1.3 ppm	N
Nonadecane (629-92-5)	0.14	0.15	N/A	N/A
Tributyl phosphate (126-73-8)	1.20	0.33	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m^3) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Dibutyl phenyl phosphate (2528-36-1)	<DL	1.50	NIOSH: The REL is 1 ppm averaged over a 10-h workshift, and a STEL of 2 ppm, not to be exceeded during any 15-min work period	N
Allyl stearate (6289-31-2)	<DL	1.50	N/A	N/A
p-dicyclohexylbenzene (1087-02-1)	<DL	0.12	N/A	N/A
(1,1'-Bicyclohexyl)-4-ylbenzene (20273-27-2)	0.19	0.32	N/A	N/A
Heptanoic acid, anhydride	2.12	11.41	N/A	N/A

(626-27-7)				
1-cyclohexyl-4-phenylbenezene (1000401-12-4)	1.08	1.23	N/A	N/A
2,7-dimethyl-3,5-Octanedione (7307-07-5)	<DL	11.33	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

As seen in Table 4, the only exceedance noted is for the chemical compound tridecane (CAS # 629-50-5) where the higher temperature yielded a measured concentration (14.86 ppbV) that did exceed the PAC-1 value of 0.0073 ppm (7.3 ppb).

This finding will be elaborated further within the “Discussion” section.

Table 5: Summary of chemicals and concentrations identified following injection of Mobil Jet Oil 387 (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Concentration (ppbV, unless otherwise noted)									
	Controls		Baseline (200°C)		200°C		250-260°C			
Compound (CAS #)	Shipping Blank	Field Blank	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Exposure Limit/Guideline (GL)	Exceeds Exposure Limit/GL (Y/N)
Triisobutyl phosphate (126-71-06)	NC	57.8	0.0187	0.0232	0.0184	0.0202	0.0190	0.0196	N/A	N/A
Tributyl phosphate (126-73-8)	NC	314	0.0899	0.289	0.0976	0.141	0.158	0.132	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Tri-m-cresyl phosphate (563-04-02)	NC	<RL	<RL	<RL	<RL	0.0579	<RL	0.164	N/A	N/A
Tri-p-cresyl phosphate (78-32-0)	NC	<RL	<RL	<RL	<RL	0.0652	<RL	0.151	N/A	N/A
Formaldehyde (50-00-0)	<RL	<RL	6.19	9.30	8.30	10.1	5.08	12.0	NIOSH: The recommended airborne exposure limit (REL) is 0.016 ppm averaged over a 10-h workshift, and no more than 0.1 ppm during any 15-min period OSHA: Permissible exposure limit (PEL) is 0.75 ppm averaged over an 8-h workshift, not to exceed 2 ppm during any 15-min period EPA AEGL-1 (interim): 0.90 ppm over 8 h	N N N
Acetaldehyde (75-07-0)	<RL	<RL	2.08	3.22	2.40	3.06	1.91	5.20	NIOSH: Lowest feasible concentration OSHA: 200 ppm averaged over an 8-h workshift ACGIH: Not to exceed 25 ppm (Ceiling)	-- N N
Acrolein (107-02-8)	<RL	<RL	<RL	<RL	<RL	0.584	0.171	0.564	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 0.3 ppm during any 15-min period OSHA: The PEL is 0.1 ppm averaged over 8 h ACGIH: The recommended airborne exposure limit is 0.1 ppm, not to be exceeded at any time EPA AEGL-1: 0.030 ppm over 8 h	N N N N
Acetone (67-64-1)	0.097 µg/ sample	0.098 µg/ sample	4.60	4.65	6.17	6.03	4.60	5.76	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Propionaldehyde (123-38-6)	<RL	<RL	0.555	0.753	0.563	1.01	0.584	1.39	ACGIH: The recommended airborne exposure limit is 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 45 ppm over 8 h	N N
Crotonaldehyde (4170-30-3)	<RL	<RL	0.971	<RL	<RL	<RL	0.897	<RL	NIOSH: Recommended time-weighted average (TWA) of 2 ppm in the air over a 10-h workday OSHA: The PEL is 2 ppm averaged over an 8-h workshift ACGIH: 0.3 ppm, not to be exceeded at any time	N N N
Methacrolein (78-85-3)	<RL	<RL	<RL	<RL	0.561	<RL	<RL	<RL	DOE/SCAPA PAC-1: 0.20 ppm	N
Methyl ethyl ketone (MEK) & Butyraldehyde (78-93-3) (123-72-8)	<RL	<RL	1.08	1.20	0.986	1.38	1.05	1.94	MEK NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period MEK OSHA: The PEL is 200 ppm averaged over an 8-h workday MEK ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL MEK EPA AEGL-1: 200 ppm over 8 h Butyraldehyde OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N N N N N
Valeraldehyde (110-62-3)	0.131 µg/ sample	0.197 µg/ sample	5.24	<RL	1.62	1.30	1.13	1.95	NIOSH: The recommended airborne exposure limit is 50 ppm averaged over a 10-h workshift ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workshift	N N
Hexaldehyde (66-25-1)	<RL	<RL	0.299	0.463	0.381	0.469	<RL	0.633	N/A	N/A
Chloromethane (74-87-3)	NC	NC	<RL	<RL	<RL	0.96	<RL	1.68	OSHA: PEL is 100 ppm over 8 h time-weighted average ACGIH: 50 ppm over 8 h TWA	N N
Methanol (67-56-1)	NC	NC	15.5	15.5	14.8	12.1	12.7	17.0	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 250 ppm as STEL during any 15-min period OSHA: The PEL is 200 ppm averaged over an 8-hour workday ACGIH: 200 ppm as an 8-h TLV®-TWA exposure, and 250 ppm as a STEL (with a skin notation) EPA AEGL-1 (interim): 270 ppm over 8 h	N N N N
Chloroethane (75-00-3)	NC	NC	<RL	<RL	<RL	<RL	<RL	1.01	NIOSH: The REL is 100 ppm averaged over a 10-h workday OSHA: The PEL is 100 ppm averaged over an 8-h workday	N N
Ethanol (64-17-5)	NC	NC	<RL	3.19	4.76	<RL	<RL	3.49	NIOSH: The REL is 1,000 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift	N N

									ACGIH: Threshold limit value (TLV®-TWA) is 1,000 ppm as a STEL	N
Acetone (67-64-1)	NC	NC	6.59	7.28	6.06	15.3	4.35	72.9	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
2-Propanol (67-63-0)	NC	NC	<RL	38.7	<RL	<RL	<RL	10.6	NIOSH: The REL is 400 ppm averaged over a 10-h workshift, not to exceed 500 ppm during any 15-min work period OSHA: The PEL is 400 ppm averaged over an 8-h work shift ACGIH: The recommended airborne exposure limit is 200 ppm averaged over an 8-h work shift, and 400 ppm as a STEL	N N N
Methyl ethyl ketone (78-93-3)	NC	NC	<RL	<RL	<RL	3.38	<RL	23.9	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Hexane (110-54-3)	NC	NC	<RL	2.61	<RL	<RL	<RL	<RL	NIOSH: The REL is 50 ppm as a TWA over 10 h OSHA: The PEL is 500 ppm as a TWA over 8 h	N N
4-Methyl-2-pentanone (MiBK) (108-10-1)	NC	NC	<RL	<RL	<RL	<RL	<RL	3.74	NIOSH: Recommended exposure limit time-weighted average (TWA) of 50 ppm over 8 h and 15-min STEL of 75 ppm OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: 50 ppm for 8-hour time weighted average (TLV®-TWA) and 75 ppm for the 15-min STEL	N N N
1,2,4-Trimethylbenzene (95-63-6)	NC	NC	0.87	<RL	<RL	<RL	<RL	<RL	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N
Hexane (110-54-3)	<RL	0.660	0.188	0.841	0.185	>RL	<RL	0.465	NIOSH: The REL is 50 ppm as a TWA over 10 h OSHA: The PEL is 500 ppm as a TWA over 8 h	N N
Methyl ethyl ketone (78-93-3)	<RL	<RL	0.125	0.245	0.173	0.290	0.205	0.338	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Tetrahydrofuran (109-99-9)	<RL	<RL	<RL	0.127	<RL	<RL	<RL	<RL	NIOSH: The REL is 200 ppm averaged over a 10-h workday and 250 ppm as a STEL OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workday and 100 ppm as a STEL	N N N
Toluene (108-88-3)	<RL	<RL	0.352	0.418	0.363	0.270	0.179	0.275	NIOSH: The REL is 100 ppm as a TWA over 10 h OSHA: The PEL is 200 ppm averaged over an 8-workshift EPA AEGL-1: 67 ppm over 8 h	N N N
Tetrachloroethylene (127-18-4)	<RL	<RL	<RL	<RL	0.133	<RL	<RL	<RL	OSHA: The PEL is 100 ppm averaged over an 8-h workday. The Ceiling concentration is 200 ppm, and the maximum peak exposure is 300 ppm for up to 5 minutes in any 3-hour period ACGIH: The threshold limit value (TLV) is 25 ppm for an 8-h workday, and the STEL is 100 ppm EPA AEGL-1 (interim): 35 ppm over 8 h	N N N
Ethyl Benzene (100-41-4)	<RL	<RL	0.160	<RL	0.155	<RL	<RL	<RL	NIOSH: REL is 100 ppm averaged over a 10 h workshift and 125 ppm not to be exceeded during any 15-minute work period OSHA: 100 ppm over an 8-h workday ACGIH: 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 33 ppm over 8 h	N N N N
m & p-xylene (108-88-3) (106-42-3)	<RL	<RL	0.888	0.586	0.855	0.583	0.264	0.260	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
Nonane (111-84-2)	<RL	<RL	3.26	1.80	2.91	1.51	0.781	0.643	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N
o-xylene (95-47-6)	<RL	<RL	0.529	0.307	0.490	0.268	0.145	<RL	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
Cumene (98-82-8)	<RL	<RL	0.108	<RL	<RL	<RL	<RL	<RL	NIOSH: The REL is 50 ppm averaged over a 10-h workday OSHA: The PEL is 50 ppm averaged over an 8-h workday ACGIH: The TLV®-TWA is 50 ppm averaged over an 8-h workday EPA AEGL-1 (interim): 50 ppm over 8 h	N N N N
n-Propylbenzene (103-65-1)	<RL	<RL	0.265	0.155	0.248	0.128	<RL	<RL	DOE/SCAPA PAC-1: 3.7 ppm	N

4-Ethyltoluene (622-96-8)	<RL	<RL	0.279	0.173	0.270	0.155	<RL	<RL	DOE/SCAPA PAC-1: 3.1 ppm	N
1,3,5-Trimethylbenzene (108-67-8)	<RL	<RL	0.404	0.273	0.390	0.233	0.152	0.138	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N
1,2,4-Trimethylbenzene (95-63-6)	<RL	<RL	1.29	1.09	1.46	0.823	0.626	0.585	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data presented in Table 5 for the engine stand test with Mobil Jet Oil 387 did not reveal exceedances of recommendations, limits, values or guidelines for any of the chemical compounds identified.

Table 6: Summary of Tentatively Identified VOCs and concentrations identified following injection of Mobil Jet Oil 387 (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)			
Compound (CAS #)	**200°C**	**250°C**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Benzene (71-43-2)	0.13	1.34	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 1 ppm in a 15-min work period OSHA: Time-weighted average (TWA) is 1 ppm for an 8-h workday, STEL is 5 ppm for any 15-min period ACGIH: The TLV®-TWA is 0.5 ppm averaged over an 8-h workshift and 2.5 ppm as a STEL EPA AEGL-1 (interim): 9 ppm over 8 h	N N N N
Pentanal (110-62-3)	<DL	1.05	N/A	N/A
Hexanal (66-25-1)	0.71	1.37	DOE/SCAPA PAC-1: 1.3 ppm	N
Pentanoic acid (109-52-4)	7.89	16.52	DOE/SCAPA PAC-1 for n-Pentanoic acid is 3.6 ppm	N
Heptanal (111-71-7)	<DL	1.57	N/A	N/A
Heptanoic acid (111-14-8)	7.88	10.36	DOE/SCAPA PAC-1: 3.9 ppm	N
Octanoic acid (124-07-2)	3.66	4.87	DOE/SCAPA PAC-1: 5.1 ppm	N
Dodecane (112-40-3)	<DL	0.29	DOE/SCAPA PAC-1: 0.12 ppm	N
n-decanoic acid (334-48-5)	3.84	3.55	N/A	N/A
Tributyl phosphate (126-73-8)	0.19	0.29	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m^3) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Heptanoic acid, anhydride (626-27-7)	3.59	<DL	N/A	N/A
Butyl diphenyl phosphate (2752-95-6)	0.89	1.04	N/A	N/A
2,7-dimethyl-3,5-Octanedione (7307-07-5)	12.44	6.74	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data from Naval Air Warfare Center Aircraft Division presented in Table 6 for the engine stand test with Mobil Jet Oil 387 did not reveal exceedances of recommendations, limits, values or guidelines for any of the chemical compounds identified.

Table 7: Summary of chemicals and concentrations identified following injection of HyJet IV-A (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Concentration (ppbV, unless otherwise noted)									
	Controls		Baseline (200°C)		200°C		260°C			
Compound (CAS #)	Shipping Blank	Field Blank	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Exposure Limit/Guideline (GL)	Exceeds Exposure Limit/GL (Y/N)
Triisobutyl phosphate (126-71-06)	NC	64.2	0.0324	0.499	0.0575	0.217	0.0324	0.0774	N/A	N/A
Tributyl phosphate (126-73-8)	NC	631	0.826	10.9	1.39	12.2	2.04	9.73	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Formaldehyde (50-00-0)	<RL	0.188 µg/ sample	11.1	10.2	11.0	13.3	8.13	18.7*	NIOSH: The recommended airborne exposure limit (REL) is 0.016 ppm averaged over a 10-h workshift, and no more than 0.1 ppm during any 15-min period OSHA: Permissible exposure limit (PEL) is 0.75 ppm averaged over an 8-h workshift, not to exceed 2 ppm during any 15-min period EPA AEGL-1 (interim): 0.90 ppm over 8 h	Y N N
Acetaldehyde (75-07-0)	<RL	<RL	1.48	1.73	1.37	3.58	1.33	9.80	NIOSH: Lowest feasible concentration OSHA: 200 ppm averaged over an 8-h workshift ACGIH: Not to exceed 25 ppm (Ceiling)	-- N N
Acrolein (107-02-8)	<RL	<RL	<RL	<RL	<RL	0.987	<RL	2.71	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 0.3 ppm during any 15-min period OSHA: The PEL is 0.1 ppm averaged over 8 h ACGIH: The recommended airborne exposure limit is 0.1 ppm, not to be exceeded at any time EPA AEGL-1: 0.030 ppm over 8 h	N N N N
Acetone (67-64-1)	0.097 µg/ sample	0.164 µg/ sample	4.72	4.54	4.31	5.14	4.16	6.50	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Propionaldehyde (123-38-6)	<RL	<RL	0.527	0.583	<RL	1.13	<RL	5.17	ACGIH: The recommended airborne exposure limit is 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 45 ppm over 8 h	N N
Crotonaldehyde (4170-30-3)	<RL	<RL	0.853	<RL	0.790	<RL	0.885	0.588	NIOSH: Recommended time-weighted average (TWA) of 2 ppm in the air over a 10-h workday OSHA: The PEL is 2 ppm averaged over an 8-h workshift ACGIH: 0.3 ppm, not to be exceeded at any time	N N N
Methacrolein (78-85-3)	<RL	<RL	1.53	<RL	<RL	<RL	<RL	0.474	DOE/SCAPA PAC-1: 0.20 ppm	N
Methyl ethyl ketone (MEK) & Butyraldehyde (78-93-3) (123-72-8)	<RL	0.046 µg/ sample	0.967	1.70	0.903	2.28	0.888	4.43	MEK NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period MEK OSHA: The PEL is 200 ppm averaged over an 8-h workday MEK ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL MEK EPA AEGL-1: 200 ppm over 8 h Butyraldehyde OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N N N N N
Valeraldehyde (110-62-3)	0.131 µg/ sample	0.039 µg/ sample	0.743	0.644	0.706	1.22	0.430	2.02	NIOSH: The recommended airborne exposure limit is 50 ppm averaged over a 10-h workshift ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workshift	N N
Hexaldehyde (66-25-1)	<RL	<RL	0.320	0.384	<RL	0.616	0.313	0.929	N/A	N/A
Triisobutyl phosphate (126-71-06)	<RL	<RL	NC	NC	NC	NC	NC	1.09	N/A	N/A
Tributyl phosphate (126-73-8)	<RL	<RL	NC	NC	NC	NC	NC	61.1	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Propene (115-07-1)	NC	NC	<RL	<RL	<RL	<RL	<RL	2.15	ACGIH: The TLV®-TWA is 500 ppm averaged over an 8-h workshift	N
Chloromethane (74-87-3)	NC	NC	0.79	<RL	<RL	<RL	1.14	<RL	OSHA: PEL is 100 ppm over 8 h time-weighted average ACGIH: 50 ppm over 8 h TWA	N N
Methanol (67-56-1)	NC	NC	93.6	17.0	16.0	11.4	12.3	13.2	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 250 ppm as STEL during any 15-min period OSHA: The PEL is 200 ppm averaged over an 8-hour workday ACGIH: 200 ppm as an 8-h TLV®-TWA exposure, and 250 ppm as a STEL (with a skin notation) EPA AEGL-1 (interim): 270 ppm over 8 h	N N N N

Ethanol (64-17-5)	NC	NC	15.1	<RL	<RL	<RL	3.87	4.91	NIOSH: The REL is 1,000 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: Threshold limit value (TLV®-TWA) is 1,000 ppm as a STEL	N N N
Acetone (67-64-1)	NC	NC	7.39	4.10	<RL	3.50	<RL	6.47	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Methyl ethyl ketone (78-93-3)	NC	NC	<RL	<RL	<RL	<RL	2.19	<RL	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Ethyl acetate (141-78-6)	NC	NC	3.83	<RL	<RL	<RL	<RL	<RL	NIOSH: The recommended airborne exposure limit is 400 ppm averaged over a 10-H workshift OSHA: The PEL is 400 ppm averaged over an 8-H workshift ACGIH: The recommended airborne exposure limit is 400 ppm averaged over an 8-H workshift	N N N
Toluene (108-88-3)	NC	NC	2.22	<RL	<RL	<RL	<RL	<RL	NIOSH: The REL is 100 ppm as a TWA over 10 h OSHA: The PEL is 200 ppm averaged over an 8-workshift EPA AEGL-1: 67 ppm over 8 h	N N N
Trans-1,2-Dichloroethene (156-60-5)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	0.368	NIOSH: The recommended airborne exposure limit is 200 ppm averaged over a 10-h workshift OSHA: The PEL is 200 ppm averaged over an 8-h workshift ACGIH: The recommended airborne exposure limit is 200 ppm averaged over an 8-hour workshift	N N N
Hexane (110-54-3)	<RL	<RL	0.461	0.358	1.62	1.02	0.198	0.242	NIOSH: The REL is 50 ppm as a TWA over 10 h OSHA: The PEL is 500 ppm as a TWA over 8 h	N N
Methyl ethyl ketone (78-93-3)	<RL	<RL	0.200	0.269	0.131	0.323	0.157	0.384	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a STEL not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Tetrahydrofuran (109-99-9)	<RL	<RL	<RL	<RL	0.248	<RL	<RL	<RL	NIOSH: The REL is 200 ppm averaged over a 10-h workday and 250 ppm as a STEL OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workday and 100 ppm as a STEL	N N N N
Cyclohexane (110-82-7)	<RL	0.650	<RL	<RL	<RL	<RL	<RL	0.184	NIOSH: The REL is 300 ppm averaged over a 10-h workshift OSHA: The PEL is 300 averaged over an 8-h workshift ACGIH: The threshold limit value (TLV®-TWA) is 100 ppm averaged over an 8-h workshift	N N N
Benzene (71-43-2)	<RL	<RL	<RL	<RL	<RL	0.428	<RL	<RL	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 1 ppm in a 15-min work period OSHA: Time-weighted average (TWA) is 1 ppm for an 8-h workday, STEL is 5 ppm for any 15-min period ACGIH: The TLV®-TWA is 0.5 ppm averaged over an 8-h workshift and 2.5 ppm as a STEL EPA AEGL-1 (interim): 9 ppm over 8 h	N N N N
Heptane (142-82-5)	<RL	<RL	<RL	<RL	<RL	0.158	0.150	0.268	NIOSH: The recommended airborne exposure limit is 85 ppm averaged over a 10-h workshift, not to exceed 440 ppm during any 15-min work period	N
Toluene (108-88-3)	<RL	<RL	<RL	<RL	0.340	0.458	0.238	0.355	NIOSH: The REL is 100 ppm as a TWA over 10 h OSHA: The PEL is 200 ppm averaged over an 8-workshift EPA AEGL-1: 67 ppm over 8 h	N N N
m & p-xylene (108-88-3) (106-42-3)	<RL	<RL	<RL	<RL	0.438	0.443	0.276	0.311	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
Nonane (111-84-2)	<RL	<RL	0.218	0.167	0.860	0.845	0.626	0.582	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N
o-xylene (95-47-6)	<RL	<RL	<RL	<RL	0.169	0.173	<RL	<RL	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
4-Ethyltoluene (622-96-8)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	0.139	DOE/SCAPA PAC-1: 3.1 ppm	N
1,3,5-Trimethylbenzene (108-67-8)	<RL	<RL	<RL	<RL	0.145	0.150	<RL	<RL	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N
1,2,4-Trimethylbenzene (95-63-6)	<RL	<RL	0.284	0.225	0.564	0.545	0.393	0.342	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

As shown in Table 7, the engine stand test with HyJet IV-A hydraulic fluid resulted in a variety of chemical compounds; however, these were all found in concentrations lower than their respective exposure recommendations, limits and/or guidelines, again with the exception of formaldehyde (CAS # 50-00-0). As before, the "higher" concentration of formaldehyde was found at the higher temperature bleed air post-injection, although formaldehyde was present in lower concentrations in pre-injection baseline samples.

This finding will be elaborated further within the "Discussion" section.

Table 8: Summary of Tentatively Identified VOCs and concentrations identified following injection of HyJet IV-A (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)			
Compound (CAS #)	**200°C**	**250°C**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
2-butene (624-64-6)	<DL	8.87	ACGIH: The TLV®-TWA is 250 ppm for butenes for 8 h	N
1-hexanol (111-27-3)	<DL	9.86	DOE/SCAPA PAC-1: 10 ppm	N
Nonane (111-84-2)	<DL	3.33	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N
2,6-dimethyloctane (2051-30-1)	<DL	2.17	N/A	N/A
n-butyl methacrylate (97-88-1)	0.99	14.62	DOE/SCAPA PAC-1: 3.3 ppm	N
1,2,3-trimethylbenzene (526-73-8)	0.32	4.05	NIOSH: The recommended airborne exposure limit (REL) is 25 ppm averaged over a 10-h workday OSHA: The PEL is 25 ppm averaged over an 8-h workday ACGIH: The recommended airborne exposure limit is 25 ppm averaged over an 8-h workday	N N N
Decane (124-18-5)	0.16	4.07	DOE/SCAPA PAC-1: 6.6 ppm	N
Undecane (1120-21-4)	0.23	3.83	DOE/SCAPA PAC-1: 0.37 ppm	N
Dodecane (112-40-3)	0.27	2.57	DOE/SCAPA PAC-1: 0.12 ppm	N
Tridecane (629-50-5)	<DL	3.61	DOE/SCAPA PAC-1: 0.0073 ppm	N
Tetradecane (629-59-4)	<DL	2.11	DOE/SCAPA PAC-1: 3.1 ppm	N
2,6,10,14-tetramethylheptadecane (18344-37-1)	1.43	0.43	N/A	N/A
Triisobutyl phosphate (126-71-06)	<DL	0.46	N/A	N/A
Pentadecane (629-62-9)	0.33	0.43	DOE/SCAPA PAC-1: 1.3 ppm	N
Butylated hydroxytoluene (128-37-0)	1.21	3.72	NIOSH: Recommended 10 mg/m^3 time-weighted average (TWA) airborne exposure limit over a 10-h workshift	N

			OSHA: Exposure limit is 10 mg/m^3 as a time-weighted average (TWA) over 8 h ACGIH: TWA exposure limit 2 mg/m^3	N N
Tributyl phosphate (126-73-8)	<DL	117.23	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m^3) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Allyl stearate (6289-31-2)	0.97	0.91	N/A	N/A
Heptanoic acid, anhydride (626-27-7)	2.26	7.15	N/A	N/A
2,7-dimethyl-3,5-Octanedione (7307-07-5)	1.05	2.89	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data presented in Table 8 did not reveal any exceedances for any of the chemical compounds' recommendations, limits, values or guidelines.

Table 9: Summary of chemicals and concentrations identified following injection of Skydrol PE-5 (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Concentration (ppbV, unless otherwise noted)									
	Controls		Baseline (200°C)		200°C		250-260°C			
Compound (CAS #)	Shipping Blank	Field Blank	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Exposure Limit(s) (in ppm)	Exceeds Exposure Limit (Y/N)
Triisobutyl phosphate (126-71-06)	NC	64.2	0.0190	0.0211	0.0392	3.56	0.168	1.80	N/A	N/A
Tributyl phosphate (126-73-8)	NC	631	0.0581	0.155	0.148	4.39	1.86	12.1	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Formaldehyde (50-00-0)	<RL	0.188 µg/ sample	1.42	7.21	4.30	6.77	7.48	9.70	NIOSH: The recommended airborne exposure limit (REL) is 0.016 ppm averaged over a 10-h workshift, and no more than 0.1 ppm during any 15-min period OSHA: Permissible exposure limit (PEL) is 0.75 ppm averaged over an 8-h workshift, not to exceed 2 ppm during any 15-min period EPA AEGL-1 (interim): 0.90 ppm over 8 h	N N N
Acetaldehyde (75-07-0)	<RL	<RL	1.56	2.39	1.85	2.23	1.85	5.14	NIOSH: Lowest feasible concentration OSHA: 200 ppm averaged over an 8-h workshift ACGIH: Not to exceed 25 ppm (Ceiling)	-- N N
Acetone (67-64-1)	0.097 µg/ sample	0.164 µg/ sample	3.04	3.35	3.49	3.60	4.14	5.37	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Propionaldehyde (123-38-6)	<RL	<RL	1.44	1.59	1.41	1.39	1.15	3.91	ACGIH: The recommended airborne exposure limit is 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 45 ppm over 8 h	N N
Crotonaldehyde (4170-30-3)	<RL	<RL	2.35	2.61	4.22	4.15	3.30	2.15	NIOSH: Recommended time-weighted average (TWA) of 2 ppm in the air over a 10-h workday OSHA: The PEL is 2 ppm averaged over an 8-h workshift ACGIH: 0.3 ppm, not to be exceeded at any time	N N N
Methyl ethyl ketone (MEK) & Butyraldehyde (78-93-3) (123-72-8)	<RL	0.046 µg/ sample	1.14	1.29	1.19	1.38	1.27	3.47	MEK NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period MEK OSHA: The PEL is 200 ppm averaged over an 8-h workday MEK ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL MEK EPA AEGL-1: 200 ppm over 8 h Butyraldehyde OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N N N N N
Benzaldehyde (100-52-7)	<RL	<RL	<RL	<RL	<RL	<RL	<RL	0.888	AIHA WEEL: An 8-h time-weighted average (TWA) of 2 ppm; STEL of 4 ppm over 15-min	N
Valeraldehyde (110-62-3)	0.131 µg/ sample	0.039 µg/ sample	0.579	0.681	0.646	0.579	0.682	1.18	NIOSH: The recommended airborne exposure limit is 50 ppm averaged over a 10-h workshift ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workshift	N N
m-Tolualdehyde (620-23-5)	<RL	<RL	<RL	0.466	<RL	<RL	<RL	0.423	N/A	N/A
Hexaldehyde (66-25-1)	<RL	<RL	<RL	0.431	0.295	0.373	0.320	0.552	N/A	N/A
Triisobutyl phosphate (126-71-06)	<RL	<RL	<RL	<RL	NC	NC	NC	12.3	N/A	N/A
Tributyl phosphate (126-73-8)	104	115	<RL	0.0566	NC	NC	NC	19.0	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Chlorodifluoromethane (75-45-6)	NC	NC	0.82	<RL	<RL	<RL	<RL	<RL	NIOSH: The REL is 1,000 ppm averaged over a 10-h workshift, not to be exceed 1,250 ppm during any 15-min work period ACGIH: TLV®-TWA is 1,000 ppm averaged over an 8-h workshift	N N
Methanol (67-56-1)	NC	NC	17.7	16.1	18.0	14.0	12.4	14.1	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 250 ppm as STEL during any 15-min period OSHA: The PEL is 200 ppm averaged over an 8-hour workday ACGIH: 200 ppm as an 8-h TLV®-TWA exposure, and 250 ppm as a STEL (with a skin notation) EPA AEGL-1 (interim): 270 ppm over 8 h	N N N N
Ethanol (64-17-5)	NC	NC	3.41	<RL	<RL	<RL	<RL	<RL	NIOSH: The REL is 1,000 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: Threshold limit value (TLV®-TWA) is 1,000 ppm as a STEL	N N N
Acetone (67-64-1)	NC	NC	6.53	4.51	3.66	3.28	<RL	5.47	NIOSH: The REL is 250 ppm averaged over a 10-h workshift	N

									OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N
Hexane (110-54-3)	<RL	<RL	0.300	0.563	<RL	11.9	<RL	0.731	NIOSH: The REL is 50 ppm as a TWA over 10 h OSHA: The PEL is 500 ppm as a TWA over 8 h	N N
Methyl ethyl ketone (78-93-3)	<RL	<RL	<RL	<RL	0.173	0.418	0.131	0.472	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Ethyl acetate (141-78-6)	<RL	<RL	<RL	<RL	<RL	0.318	<RL	<RL	NIOSH: The recommended airborne exposure limit is 400 ppm averaged over a 10-H workshift OSHA: The PEL is 400 ppm averaged over an 8-H workshift ACGIH: The recommended airborne exposure limit is 400 ppm averaged over an 8-H workshift	N N N
Tetrahydrofuran (109-99-9)	<RL	<RL	<RL	<RL	<RL	1.95	<RL	0.197	NIOSH: The REL is 200 ppm averaged over a 10-h workday and 250 ppm as a STEL OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workday and 100 ppm as a STEL	N N N
Cyclohexane (110-82-7)	<RL	0.650	<RL	<RL	<RL	0.945	<RL	<RL	NIOSH: The REL is 300 ppm averaged over a 10-h workshift OSHA: The PEL is 300 averaged over an 8-h workshift ACGIH: The threshold limit value (TLV®-TWA) is 100 ppm averaged over an 8-h workshift	N N N
2,2,4-Trimethylpentane (540-84-1)	<RL	<RL	<RL	<RL	<RL	0.130	<RL	<RL	OSHA: The time-weighted average (TWA) exposure limit is 300 ppm over a period of 8 h ACGIH: Recommended airborne exposure limit is 300 ppm averaged over an 8-h workday	N N
Heptane (142-82-5)	<RL	<RL	<RL	0.200	<RL	0.458	<RL	<RL	NIOSH: The recommended airborne exposure limit is 85 ppm averaged over a 10-h workshift, not to exceed 440 ppm during any 15-min work period	N
Toluene (108-88-3)	<RL	<RL	0.700	0.883	<RL	3.26	<RL	0.216	NIOSH: The REL is 100 ppm as a TWA over 10 h OSHA: The PEL is 200 ppm averaged over an 8-workshift EPA AEGL-1: 67 ppm over 8 h	N N N
Ethyl Benzene (100-41-4)	<RL	<RL	0.227	0.223	<RL	0.240	<RL	<RL	NIOSH: The REL is 100 ppm averaged over a 10 h workshift, not to be exceed 125 ppm during any 15-min work period OSHA: 100 ppm over an 8-h workday ACGIH: 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 33 ppm over 8 h	N N N N
m & p-xylene (108-88-3) (106-42-3)	<RL	<RL	0.823	0.777	0.257	0.835	<RL	<RL	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
Nonane (111-84-2)	<RL	<RL	0.904	0.643	0.341	0.365	0.243	0.209	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N
Styrene (100-42-5)	<RL	<RL	<RL	<RL	<RL	0.468	<RL	<RL	NIOSH: The REL is 50 ppm averaged over a 10-h shift, and the STEL is 100 ppm OSHA: The PEL is 100 ppm averaged over an 8-h shift, the STEL is 200 ppm, and the Ceiling limit is 600 ppm for a 5-minute peak in any 3-hour period ACGIH: The TLV®-TWA is 20 ppm averaged over an 8-h shift, and the 15-min short-term exposure limit is 40 ppm EPA AEGL-1 (interim): 20 ppm over 8 h	N N N N
o-xylene (95-47-6)	<RL	<RL	0.327	0.290	<RL	0.320	<RL	<RL	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
1,2,4-Trimethylbenzene (95-63-6)	<RL	<RL	0.612	0.583	0.368	0.543	0.333	0.294	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data presented in Table 9 did not reveal exceedances of any recommendation, limit, value or guideline for any of the chemical compounds identified.

Table 10: Summary of Tentatively Identified VOCs and concentrations identified following injection of Skydrol PE-5 (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)			
Compound (CAS #)	**200°C**	**250°C**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
n-butyl methacrylate (97-88-1)	<DL	4.07	DOE/SCAPA PAC-1: 3.3 ppm	N
Triisobutyl phosphate (126-71-06)	3.49	20.24	N/A	N/A
Butylated hydroxytoluene (128-37-0)	<DL	0.29	NIOSH: Recommended 10 mg/m^3 time-weighted average (TWA) airborne exposure limit over a 10-h workshift OSHA: Exposure limit is 10 mg/m^3 as a time-weighted average (TWA) over 8 h ACGIH: TWA exposure limit 2 mg/m^3	N N N
Tributyl phosphate (126-73-8)	2.21	41.83	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m^3) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
3-cyclopentylpropionic acid, 2-ethylhexyl ester (1000293-47-0)	<DL	1.50	N/A	N/A
Dibutyl phenyl phosphate (2528-36-1)	<DL	0.44	NIOSH: The REL is 1 ppm averaged over a 10-h workshift, and a STEL of 2 ppm, not to be exceeded during any 15-min work period	N
Heptanoic acid, anhydride (626-27-7)	0.26	1.49	N/A	N/A
2-Tetradecanol octanoate (55193-79-8)	0.17	1.23	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data from Naval Air Warfare Center Aircraft Division presented in Table 10 for the engine stand test performed with Skydrol PE-5 hydraulic fluid did not reveal exceedances of recommendations, limits, values or guidelines for any of the chemical compounds identified.

Table 11: Summary of chemicals and concentrations identified following injection of Safewing MP/LFD 88 Dilute (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Concentration (ppbV, unless otherwise noted)									
	Controls		Baseline (200°C)		200°C		260°C			
Compound (CAS #)	Shipping Blank	Field Blank	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Exposure Limit/Guideline (GL)	Exceeds Exposure Limit/GL (Y/N)
Triisobutyl phosphate (126-71-06)	NC	NC	0.0236	0.450	0.0245	0.523	NC	NC	N/A	N/A
Tributyl phosphate (126-73-8)	NC	NC	1.23	11.0	0.838	12.2	NC	NC	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Formaldehyde (50-00-0)	<RL	0.332 µg/ sample	6.03	9.00	6.85	8.25	NC	NC	NIOSH: The recommended airborne exposure limit (REL) is 0.016 ppm averaged over a 10-h workshift, and no more than 0.1 ppm during any 15-min period OSHA: Permissible exposure limit (PEL) is 0.75 ppm averaged over an 8-h workshift, not to exceed 2 ppm during any 15-min period EPA AEGL-1 (interim): 0.90 ppm over 8 h	N N N
Acetaldehyde (75-07-0)	<RL	<RL	1.86	2.43	1.96	4.38	NC	NC	NIOSH: Lowest feasible concentration OSHA: 200 ppm averaged over an 8-h workshift ACGIH: Not to exceed 25 ppm (Ceiling)	-- N N
Acetone (67-64-1)	0.097 µg/ sample	0.262 µg/ sample	3.10	3.51	3.12	4.32	NC	NC	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Propionaldehyde (123-38-6)	<RL	<RL	1.64	1.77	1.72	1.61	NC	NC	ACGIH: The recommended airborne exposure limit is 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 45 ppm over 8 h	N N
Crotonaldehyde (4170-30-3)	<RL	<RL	2.81	3.03	3.14	2.70	NC	NC	NIOSH: Recommended time-weighted average (TWA) of 2 ppm in the air over a 10-h workday OSHA: The PEL is 2 ppm averaged over an 8-h workshift ACGIH: 0.3 ppm, not to be exceeded at any time	N N N
Methyl ethyl ketone (MEK) & Butyraldehyde (78-93-3) (123-72-8)	<RL	0.066 µg/ sample	1.10	1.61	1.19	1.65	NC	NC	MEK NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period MEK OSHA: The PEL is 200 ppm averaged over an 8-h workday MEK ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL MEK AEGL-1: 200 ppm over 8 h Butyraldehyde OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N N N N N
Benzaldehyde (100-52-7)	<RL	<RL	<RL	<RL	<RL	0.638	NC	NC	AIHA WEEL: An 8-h time-weighted average (TWA) of 2 ppm; STEL of 4 ppm over 15-min	N
Valeraldehyde (110-62-3)	0.131 µg/ sample	0.042 µg/ sample	0.703	0.697	0.906	3.44	NC	NC	NIOSH: The recommended airborne exposure limit is 50 ppm averaged over a 10-h workshift ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workshift	N N
m-Tolualdehyde (620-23-5)	<RL	<RL	0.653	0.507	0.796	0.490	NC	NC	N/A	N/A
Hexaldehyde (66-25-1)	<RL	<RL	0.409	0.420	0.356	0.395	NC	NC	N/A	N/A
Chloromethane (74-87-3)	NC	NC	0.80	<RL	NC	<RL	NC	NC	OSHA: PEL is 100 ppm over 8 h time-weighted average ACGIH: 50 ppm over 8 h TWA	N N
Methanol (67-56-1)	NC	NC	13.5	18.8	NC	19.2	NC	NC	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 250 ppm as STEL during any 15-min period OSHA: The PEL is 200 ppm averaged over an 8-hour workday ACGIH: 200 ppm as an 8-h TLV®-TWA exposure, and 250 ppm as a STEL (with a skin notation) EPA AEGL-1 (interim): 270 ppm over 8 h	N N N N
Acetone (67-64-1)	NC	NC	4.37	6.60	NC	7.47	NC	NC	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the STEL is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
2-Propanol (67-63-0)	NC	NC	9.53	<RL	NC	<RL	NC	NC	NIOSH: The REL is 400 ppm averaged over a 10-h workshift, not to exceed 500 ppm during any 15-min work period OSHA: The PEL is 400 ppm averaged over an 8-h work shift ACGIH: The recommended airborne exposure limit is 200 ppm averaged over an 8-h work shift, and 400 ppm as a STEL	N N N

Carbon disulfide (75-15-0)	NC	NC	<RL	3.66	NC	<RL	NC	NC	NIOSH: The REL is 1 ppm averaged over a 10-h workday, with a maximum of 10 ppm for any 15-min period OSHA: The PEL is 20 ppm averaged over an 8-h workday, with a ceiling of 30 ppm and a maximum peak of 100 ppm for any 30-min period	N N
Vinyl acetate (108-05-4)	NC	<RL	<RL	<RL	0.162	<RL	NC	NC	NIOSH: Recommends a ceiling limit of 4 ppm for a 15-min exposure OSHA: Sets a limit of 10 ppm in workroom air over an 8-h shift and a STEL of 20 ppm for 15-min ACGIH: Recommends a threshold limit (TLV®-TWA) of 10 ppm averaged over an 8-h shift and STEL of 15 ppm EPA AEGL-1: 6.7 ppm over 8 h	N N N N
Hexane (110-54-3)	NC	1.77	0.295	0.367	0.148	0.243	NC	NC	NIOSH: The REL is 50 ppm as a TWA over 10-h OSHA: The PEL is 500 ppm as a TWA over 8 h	N N
Methyl ethyl ketone (78-93-3)	NC	<RL	0.161	0.270	<RL	0.180	NC	NC	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Cyclohexane (110-82-7)	NC	1.01	0.141	<RL	<RL	0.172	NC	NC	NIOSH: The REL is 300 ppm averaged over a 10-h workshift OSHA: The PEL is 300 averaged over an 8-h workshift ACGIH: The threshold limit value (TLV®-TWA) is 100 ppm averaged over an 8-h workshift	N N N
Heptane (142-82-5)	NC	<RL	0.268	0.317	0.104	0.120	NC	NC	NIOSH: The recommended airborne exposure limit is 85 ppm averaged over a 10-h workshift, not to exceed 440 ppm during any 15-min work period	N
Toluene (108-88-3)	NC	<RL	0.611	0.797	0.234	0.265	NC	NC	NIOSH: The REL is 100 ppm as a TWA over 10 h OSHA: The PEL is 200 ppm averaged over an 8-workshift EPA AEGL-1: 67 ppm over 8 h	N N N
Ethyl benzene (100-41-4)	NC	<RL	0.164	0.250	<RL	<RL	NC	NC	OSHA: Permissible exposure limit: 100 parts per million (ppm) as an average over an 8-hour workday, 40-hour workweek EPA AEGL-1 (interim): 33 ppm over 8 h	N N
m & p-xylene (108-88-3) (106-42-3)	NC	<RL	0.575	0.857	0.268	0.291	NC	NC	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
Nonane (111-84-2)	NC	<RL	0.557	0.563	0.206	0.185	NC	NC	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N
o-xylene (95-47-6)	NC	<RL	0.234	0.293	0.106	0.117	NC	NC	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
1,2,4-Trimethylbenzene (95-63-6)	NC	<RL	0.407	0.493	0.318	0.322	NC	NC	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data presented in Table 11 for the engine stand test with the deicing fluid did not reveal concentrations that exceeded any recommendations, limits, values or guidelines for the chemical compounds identified.

Table 12: Summary of Tentatively Identified VOCs and concentrations identified following injection of Safewing MP/LFD 88 Dilute (Engine Stand Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)			
Compound (CAS #)	**200°C**	**250°C**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
3-hydroxy-2-butanone (513-86-0)	32.82	NC	For 2-butanone: NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL AEGL-1: 200 ppm over 8 h	N N N N
Propylene glycol (57-55-6)	128.4	NC	AIHA WEEL: 3.2 ppm (10 mg/m^3) averaged over an 8-h workshift	N
Propylene glycol (57-55-6)	40.99	NC	AIHA WEEL: 3.2 ppm (10 mg/m^3) averaged over an 8-h workshift	N
Heptanoic acid, anhydride (626-27-7)	0.59	NC	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data from Naval Air Warfare Center Aircraft Division identified very few compounds in the bleed air from the deicing fluid injection engine stand test. As shown in Table 12, only three different compounds were identified, one (Heptanoic acid, anhydride CAS # 626-27-7) does not have exposure limits/guidelines developed, the other two, 3-hydroxy-2-butanone (CAS # 513-86-0) and propylene glycol (CAS # 57-55-6) did not exceed their recommendations, limits or guidelines.

Chemicals Identified in Ground-Based On Aircraft Tests

The ground-based aircraft tests were performed with three different fluids: Mobil Jet Oil II (standard oil), Eastman Turbo Oil 2197 (high thermal stability oil), and Skydrol PE-5 (hydraulic fluid).

The following tables (Tables 13-21) describe the chemical compounds identified and their concentrations, exposure limits/guidelines and whether or not (Y/N) the concentrations reported exceeded a given recommendation, limit or guideline, the concentration of which is indicated by an asterisk (*) in the table.

Please note that chemical concentrations are provided in parts per billion by volume (ppbV) whereas exposure limits/guidelines are presented in parts per million (ppm) where 1 ppm is equal to 1,000 ppb.

Table 13: Summary of chemicals and concentrations identified following injection of 5 ppm Mobil Jet Oil II into the APU (On Aircraft Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Field Blank Concentration (ppbv)				Baseline (220°C)		220°C			
Compound (CAS #)	**Ambient Air (APU inlet)**	**Ozone/ VOC converter (Inlet)**	**Ozone/ VOC converter (Exit)**	**Pack Exit**	**Sample Location**	**Conc. (ppbv)**	**Sample Location**	**Conc. (ppbv)**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Tributyl phosphate (126-73-8)	<RL	<RL	<RL	<RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.112 0.011 <RL 0.041	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.059 0.080 0.135 0.10	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Tris(2-butoxyethyl) phosphate (78-51-3)	0.11	<RL	<RL	<RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.011 <RL <RL 0.037	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL <RL <RL	DOE/SCAPA PAC-1: 0.55 ppm	N
Tri-m-cresyl phosphate (563-04-02)	<RL	<RL	<RL	<RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL 0.058 0.0215 0.0748	N/A	N/A
Tri-p-cresyl phosphate (78-32-0)	<RL	<RL	<RL	<RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL 0.065 0.0232 0.0759	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

Only four compounds were identified and quantified in the ground-based on aircraft test following injection of 5 ppmW of Mobil Jet Oil II into the APU. Of those four compounds, two (m- and p-cresyl phosphate) do not have specific exposure limits/guidelines, while the other two did not exceed their recommendation, limit, value or guideline, as shown in Table 13.

Table 14: Summary of chemicals and concentrations identified following injection of 10 ppm Mobil Jet Oil II into the APU (On Aircraft Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Field Blank Concentration (ppbV)				Baseline (220°C)		220°C			
Compound (CAS #)	**Ambient Air (APU inlet)**	**Ozone/ VOC converter (Inlet)**	**Ozone/ VOC converter (Exit)**	**Pack Exit**	**Sample Location**	**Conc. (ppbV)**	**Sample Location**	**Conc. (ppbV)**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Tributyl phosphate (126-73-8)	<RL	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC NC NC NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.07 <RL 0.036	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Tri-m-cresyl phosphate (563-04-02)	<RL	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC NC NC NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.70 0.112 0.325	N/A	N/A
Tri-p-cresyl phosphate (78-32-0)	<RL	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC NC NC NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.78 0.200 0.298	N/A	N/A
Methyl ethyl ketone (78-93-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC NC NC NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.276 1.10 8.30 4.64	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Heptane (142-82-5)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC NC NC NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.178 <RL <RL <RL	NIOSH: The recommended airborne exposure limit is 85 ppm averaged over a 10-h workshift, not to exceed 440 ppm during any 15-min work period	N
2-Hexanone (591-78-6)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC NC NC NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL 0.256 1.19 0.923	NIOSH: The REL is 1 ppm as a TWA over 10 h OSHA: The PEL is 100 ppm averaged over an 8-h workshift	N N
m & p-Xylene (108-88-3) (106-42-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC NC NC NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.330 <RL <RL <RL	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
Nonane (111-84-2)	NC	NC	NC	NC	Ambient Air (APU inlet)	NC	Ambient Air (APU inlet)	1.14	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N

					---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC NC NC	---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	0.193 <RL <RL		
o-Xylene (95-47-6)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC NC NC NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	0.175 <RL <RL <RL	For Xylenes: NIOSH: The REL is 100 ppm averaged over a 10-h workshift, and not to exceed 150 ppm during any 15-min work period OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The TLV®-TWA is 100 ppm averaged over an 8-h workshift, and 150 ppm as a STEL EPA AEGL-1: 130 ppm over 8 h	N N N N
1,2,4-Trimethylbenzene (95-63-6)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC NC NC NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	0.552 <RL <RL <RL	NIOSH: 25 ppm averaged over a 10-h workday EPA AEGL-1: 45 ppm over 8 h	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data presented from the on aircraft test with injection of 10 ppmW Mobil Jet Oil II into the APU (Table 14) did not reveal exceedances of any recommendations, limits, values or guidelines for the chemical compounds identified.

Table 15: Summary of Tentatively Identified VOCs and concentrations identified following injection of Mobil Jet Oil II into the APU (On Aircraft Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)			
Compound (CAS #)	**180°C (5 ppmW injected)**	**180°C (10 ppmW injected)**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Acetone (67-64-1)	2.9	2.0	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Methacrolein (78-85-3)	2.6	4.4	DOE/SCAPA PAC-1: 0.20 ppm	N
Butanal (123-72-8)	6.2	4.6	OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N
Acetic acid (64-19-7)	25.4	17.3	NIOSH: The REL is 10 ppm averaged over a 10-h workshift, not to exceed 15 ppm during any 15-min work period OSHA: The PEL is 10 ppm over an 8-h workshift ACGIH: The TLV®-TWA is 10 ppm for an 8-h workday, and 15 ppm for periods not exceeding 15 min	N N N
Pentanal (110-62-3)	7.2	8.1	N/A	N/A
Butanoic acid (107-92-6)	4.1	3.0	DOE/SCAPA PAC-1: 1.7 ppm	N

2-Hexanone (591-78-6)	1.9	2.1	NIOSH: The REL is 1 ppm as a TWA over 10 h OSHA: The PEL is 100 ppm averaged over an 8-h workshift	N N
Butynediol (110-65-6)	12.8	30.0	DOE/SCAPA PAC-1: 0.31 ppm	N
Hexanal (66-25-1)	10.9	14.5	DOE/SCAPA PAC-1: 1.3 ppm	N
2-Methylbutanoic acid (116-53-0)	58.2	102.3	N/A	N/A
Heptanal (111-71-7)	4.0	8.3	N/A	N/A
Pentanoic acid (109-52-4)	136.3	347.5	DOE/SCAPA PAC-1 for n-Pentanoic acid is 3.6 ppm	N
2(3H)-Furanone, dihydro-5-methyl- (108-29-2)	2.4	2.2	N/A	N/A
Hexanoic acid (142-62-1)	15.0	20.8	DOE/SCAPA PAC-1: 0.46 ppm	N
Octanal (124-13-0)	1.9	2.7	DOE/SCAPA PAC-1: 3.2 ppm	N
2-Methylhexanoic acid (4536-23-6)	5.4	6.2	N/A	N/A
p/m/o-cresol (1319-77-3)	7.5	20.7	DOE/SCAPA PAC-1: For all isomers of cresol, 14 ppm For p-cresol: NIOSH: The REL is 2.3 ppm averaged over a 10-h workday OSHA: The PEL is 5 ppm averaged over an 8-h workshift ACGIH: Recommends an airborne exposure limit of 5 ppm averaged over an 8-h workday	N N N N
Heptanoic acid (111-14-8)	160.7	515.8	DOE/SCAPA PAC-1: 3.9 ppm	N
Nonanal (124-19-6)	3.0	3.8	DOE/SCAPA PAC-1: 2.6 ppm	N
2(3H)-Furanone, dihydro-5-propyl- (105-21-5)	3.3	2.8	N/A	N/A
3,5,5-Trimethylhexanoic acid (3302-10-1)	<DL	14.6	N/A	N/A
Octanoic acid (124-07-2)	64.0	139.5	DOE/SCAPA PAC-1: 5.1 ppm	N
3,5-Dimethyl-4-heptanone (19549-84-9)	10.0	32.5	For 4-heptanone: NIOSH: 50 ppm averaged over a 10-h workshift ACGIH: 50 ppm averaged over an 8-h workshift	N N
Allyl isovalerate (2835-39-4)	12.5	44.0	N/A	N/A
2(3H)-Furanone, 5-butyldihydro- (104-50-7)	1.5	1.2	N/A	N/A
Nonanoic acid (112-05-0)	1.0	7.9	DOE/SCAPA PAC-1: 2.3 ppm	N
Decanoic acid (334-48-5)	24.0	34.3	N/A	N/A
Allyl heptanoate (142-19-8)	10.8	49.4	N/A	N/A
Allyl octanoate (4230-97-1)	5.7	11.0	N/A	N/A
Allyl decanoate (57856-81-2)	<DL	3.8	N/A	N/A
N-phenyl-1-naphthalenamine (90-30-2)	<DL	3.8	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)
ppmW – Parts per million by weight

Data from Naval Air Warfare Center Aircraft Division identifying compounds found in the on aircraft test with Mobil Jet Oil II identified a number of chemical compounds for which there are no specified exposure recommendation, limit or guideline (Table 15). For those compounds that did have exposure recommendations, limits or guidelines, none were exceeded.

Table 16: Summary of chemicals and concentrations identified following injection of Mobil Jet Oil II into the Engine (On Aircraft Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Field Blank Concentration (ppbV)				Baseline (315°C)		#3 Engine (315°C)			
Compound (CAS #)	**Ambient Air (APU inlet)**	**Ozone/ VOC converter (Inlet)**	**Ozone/ VOC converter (Exit)**	**Pack Exit**	**Sample Location**	**Conc. (ppbV)**	**Sample Location**	**Conc. (ppbV)**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Tributyl phosphate (126-73-8)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.007 NC <RL 0.022	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL NC 0.023	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Tri-m-cresyl phosphate (563-04-02)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.012 NC <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.034 NC 0.055	N/A	N/A
Tri-p-cresyl phosphate (78-32-0)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.021 NC 0.005 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.044 NC 0.052	N/A	N/A
Formaldehyde (50-00-0)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	2.91 7.20 27.4* 21.9*	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	4.25 14.3 58.1* 72.5*	NIOSH: The recommended airborne exposure limit (REL) is 0.016 ppm averaged over a 10-h workshift, and no more than 0.1 ppm during any 15-min period OSHA: Permissible exposure limit (PEL) is 0.75 ppm averaged over an 8-h workshift, not to exceed 2 ppm during any 15-min period EPA AEGL-1 (interim): 0.90 ppm over 8 h	Y N N
Acetaldehyde (75-07-0)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	1.51 2.41 12.7 11.3	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	1.64 7.56 40.0 28.9	NIOSH: Lowest feasible concentration OSHA: 200 ppm averaged over an 8-h workshift ACGIH: Not to exceed 25 ppm (Ceiling)	-- N N
Acrolein (107-02-8)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 0.597 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 1.03 <RL	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 0.3 ppm during any 15-min period OSHA: The PEL is 0.1 ppm averaged over 8 h ACGIH: The recommended airborne exposure limit is 0.1 ppm, not to be exceeded at any time EPA AEGL-1: 0.030 ppm over 8 h	N N N N
Acetone (67-64-1)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	3.48 3.54 5.50 4.15	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	1.82 1.84 5.03 <RL	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N

Propionaldehyde (123-38-6)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.696 1.02 1.92 2.70	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	1.47 3.73 10.6 11.0	ACGIH: The recommended airborne exposure limit is 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 45 ppm over 8 h	N N
Crotonaldehyde (4170-30-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	2.32 0.311 0.675 4.49	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	4.38 3.00 1.66 5.05	NIOSH: Recommended time-weighted average (TWA) of 2 ppm in the air over a 10-h workday. OSHA: The PEL is 2 ppm averaged over an 8-h workshift ACGIH: 0.3 ppm, not to be exceeded at any time	N N N
Methacrolein (78-85-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.474 <RL <RL 0.640	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	1.08 <RL 1.76 <RL	DOE/SCAPA PAC-1: 0.20 ppm	N
Methyl ethyl ketone (MEK) & Butyraldehyde (78-93-3) (123-72-8)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	1.35 1.13 3.35 3.44	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.793 2.64 14.8 7.85	MEK NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period MEK OSHA: The PEL is 200 ppm averaged over an 8-h workday MEK ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL MEK EPA AEGL-1: 200 ppm over 8 h Butyraldehyde OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N N N N N
Valeraldehyde (110-62-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.934 0.926 1.51 1.45	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.772 3.11 3.91 6.02	NIOSH: The recommended airborne exposure limit is 50 ppm averaged over a 10-h workshift ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workshift	N N
m-Tolualdehyde (620-23-5)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.546 <RL <RL <RL	N/A	N/A
Hexaldehyde (66-25-1)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 0.338 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL 0.695 3.34 3.04	N/A	N/A
Methyl ethyl ketone (78-93-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.523 0.585 2.22 2.61	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.565 2.15 < RL 7.35	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N

Toluene (108-88-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 0.744 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL <RL <RL	NIOSH: The REL is 100 ppm as a TWA over 10 h OSHA: The PEL is 200 ppm averaged over an 8-workshift EPA AEGL-1: 67 ppm over 8 h	N N N
2-Hexanone (591-78-6)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL 0.453 <RL 0.965	NIOSH: The REL is 1 ppm as a TWA over 10 h OSHA: The PEL is 100 ppm averaged over an 8-h workshift	N N
Nonane (111-84-2)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL <RL 0.260	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

As seen in Table 16, formaldehyde (CAS # 50-00-0) was again quantified at levels that technically exceed the NIOSH *recommended* exposure limit (REL) of 0.016 ppm (16 ppb), *if* the concentrations measured here (22-73 ppbV) were maintained over a 10-h duration. Of note, the concentrations of formaldehyde identified here do not exceed OSHA's PEL (0.75 ppm (750 ppb) over 8 h) or the EPA's AEGL-1 value (0.90 ppm (900 ppb) over 8h).

This finding will be further elaborated within the "Discussion" section.

Table 17: Summary of Tentatively Identified VOCs and concentrations identified following injection of Mobil Jet Oil II into the Engine (On Aircraft Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)			
Compound (CAS #)	**220°C**	**315°C**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Acetone (67-64-1)	1.7	2.3	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Methacrolein (78-85-3)	0.8	1.4	DOE/SCAPA PAC-1: 0.20 ppm	N
Butanal (123-72-8)	1.1	5.0	OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N
2-Butanone (78-93-3)	2.8	8.9	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday	N N

			ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N
Acetic acid (64-19-7)	6.5	15.6	NIOSH: The REL is 10 ppm averaged over a 10-h workshift, not to exceed 15 ppm during any 15-min work period OSHA: The PEL is 10 ppm over an 8-h workshift ACGIH: The TLV®-TWA is 10 ppm for an 8-h workday, and 15 ppm for periods not exceeding 15 min	N N N
Pentanal (110-62-3)	2.2	3.7	N/A	N/A
Butanoic acid (107-92-6)	1.2	4.5	DOE/SCAPA PAC-1: 1.7 ppm	N
Butynediol (110-65-6)	7.5	6.8	DOE/SCAPA PAC-1: 0.31 ppm	N
Hexanal (66-25-1)	4.2	5.6	DOE/SCAPA PAC-1: 1.3 ppm	N
2-Methylbutanoic acid (116-53-0)	33.4	50.3	N/A	N/A
Pentanoic acid (109-52-4)	73.3	118.9	DOE/SCAPA PAC-1 for n-Pentanoic acid is 3.6 ppm	N
Heptanal (111-71-7)	0.9	2.21	N/A	N/A
2(3H)-Furanone, dihydro-5-methyl- (108-29-2)	1.1	2.2	N/A	N/A
Hexanoic acid (142-62-1)	6.5	7.2	DOE/SCAPA PAC-1: 0.46 ppm	N
2-Methylhexanoic acid (4536-23-6)	2.1	2.2	N/A	N/A
p/m/o-cresol	10.2	5.4	DOE/SCAPA PAC-1: For all isomers of cresol, 14 ppm For p-cresol: NIOSH: The REL is 2.3 ppm averaged over a 10-h workday OSHA: The PEL is 5 ppm averaged over an 8-h workshift ACGIH: Recommends an airborne exposure limit of 5 ppm averaged over an 8-h workday	N N N N
Heptanoic acid (111-14-8)	96.0	152.7	DOE/SCAPA PAC-1: 3.9 ppm	N
Nonanal (124-19-6)	0.6	0.9	DOE/SCAPA PAC-1: 2.6 ppm	N
2(3H)-Furanone, dihydro-5-propyl- (105-21-5)	1.4	2.5	N/A	N/A
Octanoic acid (124-07-2)	32.6	41.8	DOE/SCAPA PAC-1: 5.1 ppm	N
3,5-Dimethyl-4-heptanone (19549-84-9)	6.3	9.3	For 4-heptanone: NIOSH: 50 ppm averaged over a 10-h workshift ACGIH: 50 ppm averaged over an 8-h workshift	N N
Allyl isovalerate (2835-39-4)	8.4	12.7	N/A	N/A
Decanoic acid (334-48-5)	9.2	12.7	N/A	N/A
Allyl heptanoate (142-19-8)	7.7	11.4	N/A	N/A
Allyl octanoate (4230-97-1)	3.3	1.8	N/A	N/A
Allyl decanoate (57856-81-2)	1.1	<DL	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data from Naval Air Warfare Center Aircraft Division presented in Table 17 did not reveal exceedances of any recommendation, limit, value or guideline for any of the chemical compounds identified from injection of Mobil Jet Oil II into the engine for the on aircraft test.

Table 18: Summary of chemicals and concentrations identified following injection of Eastman Turbo Oil 2197 into the Engine (On Aircraft Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Field Blank Concentration (ppbV)				Baseline (315°C)		#3 Engine (315°C)			
Compound (CAS #)	**Ambient Air (APU inlet)**	**Ozone/ VOC converter (Inlet)**	**Ozone/ VOC converter (Exit)**	**Pack Exit**	**Sample Location**	**Conc. (ppbV)**	**Sample Location**	**Conc. (ppbV)**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Tributyl phosphate (126-73-8)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.128 <RL 0.0483	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.0127 <RL 0.0614	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Tri-m-cresyl phosphate (563-04-02)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL <RL 0.0100	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.3530 0.0087 0.0515	N/A	N/A
Tri-p-cresyl phosphate (78-32-0)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.3836 0.0094 0.0505	N/A	N/A
Formaldehyde (50-00-0)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 6.87 33.8* 1.38	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	1.41 8.40 97.8* NC	NIOSH: The recommended airborne exposure limit (REL) is 0.016 ppm averaged over a 10-h workshift, and no more than 0.1 ppm during any 15-min period OSHA: Permissible exposure limit (PEL) is 0.75 ppm averaged over an 8-h workshift, not to exceed 2 ppm during any 15-min period EPA AEGL-1 (interim): 0.90 ppm over 8 h	Y N N
Acetaldehyde (75-07-0)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 2.14 9.61 0.422	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL 2.54 28.0 NC	NIOSH: Lowest feasible concentration OSHA: 200 ppm averaged over an 8-h workshift ACGIH: Not to exceed 25 ppm (Ceiling)	N N N
Acrolein (107-02-8)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 1.94 NC	NIOSH: The REL is 0.1 ppm averaged over a 10-h workshift, not to exceed 0.3 ppm during any 15-min period OSHA: The PEL is 0.1 ppm averaged over 8 h ACGIH: The recommended airborne exposure limit is 0.1 ppm, not to be exceeded at any time EPA AEGL-1: 0.030 ppm over 8 h	N N N N
Acetone (67-64-1)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 3.74 2.50 1.97	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	3.35 4.07 4.39 NC	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N

Propionaldehyde (123-38-6)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL 1.57 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL 0.793 10.6 NC	ACGIH: The recommended airborne exposure limit is 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 45 ppm over 8 h	N N
Crotonaldehyde (4170-30-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL 0.746 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 0.711 NC	NIOSH: Recommended time-weighted average (TWA) of 2 ppm in the air over a 10-h workday. OSHA: The PEL is 2 ppm averaged over an 8-h workshift ACGIH: 0.3 ppm, not to be exceeded at any time	N N N
Methacrolein (78-85-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 1.04 NC	DOE/SCAPA PAC-1: 0.20 ppm	N
Methyl ethyl ketone (MEK) & Butyraldehyde (78-93-3) (123-72-8)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.458 2.44 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL 1.12 12.7 NC	MEK NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period MEK OSHA: The PEL is 200 ppm averaged over an 8-h workday MEK ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL MEK EPA AEGL-1: 200 ppm over 8 h Butyraldehyde OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N N N N N
Valeraldehyde (110-62-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.792 1.62 0.374	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.859 <RL 3.61 NC	NIOSH: The recommended airborne exposure limit is 50 ppm averaged over a 10-h workshift ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workshift	N N
m-Tolualdehyde (620-23-5)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL 0.481 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 1.18 NC	N/A	N/A
Hexaldehyde (66-25-1)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL 0.320 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 3.27 NC	N/A	N/A
Pyrene (129-00-0)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL 0.0005 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL <RL <RL	NIOSH: The REL is 0.1 mg/m^3 averaged over a 10-h workday (applies to coal tar pitch volatiles) OSHA: The PEL is 0.2 mg/m^3 (Coal Tar Pitch Volatiles – as the Benzene soluble fraction)) averaged over an 8-h workshift ACGIH: The TLV®-TWA is 0.2 mg/m^3 (Coal Tar Pitch Volatiles – as the Benzene soluble aerosol) averaged over an 8-h workshift	N N N

Methyl ethyl ketone (78-93-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.193 0.313 1.66 1.56	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	0.189 0.327 1.46 1.39	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
2-Hexanone (591-78-6)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	<RL <RL 0.418 0.400	NIOSH: The REL is 1 ppm as a TWA over 10 h OSHA: The PEL is 100 ppm averaged over an 8-h workshift	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

As shown in Table 18, formaldehyde (CAS # 50-00-0) was again quantified at levels that exceed the NIOSH *recommended* exposure limit (REL) of 0.016 ppm (16 ppb), *if* the concentrations measured here (34 and 98 ppb) were maintained over a 10-h duration. They do not, however, exceed NIOSH's recommended 15-min exposure limit of 0.1 ppm (100 ppb), nor do they exceed the accepted OSHA PEL of 0.75 ppm (750 ppb) over 8 h or the EPA AEGL-1 value of 0.90 ppm (900 ppb) over 8 h.

This finding will be further elaborated within the "Discussion" section.

Table 19: Summary of Tentatively Identified VOCs and concentrations identified following injection of Eastman Turbo Oil 2197 into the Engine (On Aircraft Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)			
Compound (CAS #)	**220°C**	**315°C**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Acetone (67-64-1)	<DL	3.6	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Methacrolein (78-85-3)	0.5	1.5	DOE/SCAPA PAC-1: 0.20 ppm	N
Butanal (123-72-8)	1.4	3.2	OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N
Acetic acid (64-19-7)	3.2	14.8	NIOSH: The REL is 10 ppm averaged over a 10-h workshift, not to exceed 15 ppm during any 15-min work period OSHA: The PEL is 10 ppm over an 8-h workshift ACGIH: The TLV®-TWA is 10 ppm for an 8-h workday, and 15 ppm for periods not exceeding 15 min	N N N
Pentanal (110-62-3)	0.9	3.0	N/A	N/A
Butanoic acid (107-92-6)	1.5	3.9	DOE/SCAPA PAC-1: 1.7 ppm	N

4,4-Dimethyl-2-pentanone (590-50-1)	0.4	4.1	For 4-Methyl-2-pentanone: NIOSH: Recommended exposure limit time-weighted average (TWA) of 50 ppm over 8 h and 15-min STEL of 75 ppm OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: 50 ppm for 8-hour time weighted average (TLV®-TWA) and 75 ppm for the 15-min STEL	N N N
Butynediol (110-65-6)	5.2	7.6	DOE/SCAPA PAC-1: 0.31 ppm	N
Hexanal (66-25-1)	1.1	4.4	DOE/SCAPA PAC-1: 1.3 ppm	N
2-Methylbutanoic acid (116-53-0)	1.5	3.1	N/A	N/A
Pentanoic acid (109-52-4)	137.3	198.3	DOE/SCAPA PAC-1 for n-Pentanoic acid is 3.6 ppm	N
2(3H)-Furanone, dihydro-5-methyl- (108-29-2)	0.8	2.5	N/A	N/A
Hexanoic acid (142-62-1)	0.8	2.4	DOE/SCAPA PAC-1: 0.46 ppm	N
Octanal (124-13-0)	0.8	2.4	DOE/SCAPA PAC-1: 3.2 ppm	N
p/m/o-cresol	3.7	2.7	DOE/SCAPA PAC-1: For all isomers of cresol, 14 ppm For p-cresol: NIOSH: The REL is 2.3 ppm averaged over a 10-h workday OSHA: The PEL is 5 ppm averaged over an 8-h workshift ACGIH: Recommends an airborne exposure limit of 5 ppm averaged over an 8-h workday	N N N N
Heptanoic acid (111-14-8)	69.9	106.5	DOE/SCAPA PAC-1: 3.9 ppm	N
3,5,5-Trimethylhexanoic acid (3302-10-1)	17.5	43.6	N/A	N/A
Octanoic acid (124-07-2)	2.4	5.7	DOE/SCAPA PAC-1: 5.1 ppm	N
Allyl isovalerate (2835-39-4)	17.5	26.4	N/A	N/A
Nonanoic acid (112-05-0)	17.0	43.0	DOE/SCAPA PAC-1: 2.3 ppm	N
Decanoic acid (334-48-5)	0.3	2.4	N/A	N/A
Allyl heptanoate (142-19-8)	5.9	10.2	N/A	N/A
Allyl octanoate (4230-97-1)	2.7	6.2	N/A	N/A
Allyl decanoate (57856-81-2)	0.4	2.4	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The Naval Air Warfare Center Aircraft Division data presented in Table 19 for tentatively identified VOCs identified following injection of Eastman Turbo Oil 2197 into the Engine (on aircraft test) did not reveal exceedances of recommendations, limits, values or guidelines for any of the chemical compounds identified. A number of compounds did not have established or published recommendations, limits, values or guidelines; however, the concentrations overall were very low and are unlikely to be a cause for concern.

Table 20: Summary of chemicals and concentrations identified following injection of 5 ppm Skydrol PE-5 into the APU (On Aircraft Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline.

	Field Blank Concentration (ppbV)				Baseline (220°C)		220°C			
Compound (CAS #)	**Ambient Air (APU inlet)**	**Ozone/ VOC converter (Inlet)**	**Ozone/ VOC converter (Exit)**	**Pack Exit**	**Sample Location**	**Conc. (ppbV)**	**Sample Location**	**Conc. (ppbV)**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Triisobutyl phosphate (126-71-6)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 1.1286 0.2909 1.5305	N/A	N/A
Tributyl phosphate (126-73-8)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.084 0.028 0.033	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL <RL <RL	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m³) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
Triphenyl phosphate (115-86-6)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 1.2360 0.2236 0.0673	NIOSH: 3 mg/m³ averaged over a 10-h workday OSHA: 3 mg/m³ averaged over a 8-h workday	N N
Tris(2-butoxyethyl) phosphate (78-51-3)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC <RL <RL <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.0164 <RL 0.0291	DOD/SCAPA PAC-1: 0.55 ppm	N/A
Tri-m-cresyl phosphate (563-04-02)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.063 0.166 <RL	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.0352 0.0178 <RL	N/A	N/A
Tri-p-cresyl phosphate (78-32-0)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.056 0.149 0.011	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 0.0242 0.0172 <RL	N/A	N/A
Formaldehyde (50-00-0)	NC	NC	NC	NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC NC NC NC	Ambient Air (APU inlet) Ozone/ VOC converter (Inlet) Ozone/ VOC converter (Exit) Pack Exit	NC 3.89 NC NC	NIOSH: The recommended airborne exposure limit (REL) is 0.016 ppm averaged over a 10-h workshift, and no more than 0.1 ppm during any 15-min period OSHA: Permissible exposure limit (PEL) is 0.75 ppm averaged over an 8-h workshift, not to exceed 2 ppm during any 15-min period EPA AEGL-1 (interim): 0.90 ppm over 8 h	N N N
Acetaldehyde (75-07-0)	NC	NC	NC	NC	Ambient Air (APU inlet)	NC	Ambient Air (APU inlet)	NC	NIOSH: Lowest feasible concentration OSHA: 200 ppm averaged over an 8-h workshift	-- N

					---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC NC NC	---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	1.74 NC NC	ACGIH: Not to exceed 25 ppm (Ceiling)	N
Acetone (67-64-1)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC NC NC NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC 4.28 NC NC	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Propionaldehyde (123-38-6)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC NC NC NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC 2.14 NC NC	ACGIH: The recommended airborne exposure limit is 20 ppm averaged over an 8-h workshift EPA AEGL-1 (interim): 45 ppm over 8 h	N N
Methyl ethyl ketone (MEK) & Butyraldehyde (78-93-3) (123-72-8)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC NC NC NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC 2.41 NC NC	MEK NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period MEK OSHA: The PEL is 200 ppm averaged over an 8-h workday MEK ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL MEK EPA AEGL-1: 200 ppm over 8 h Butyraldehyde OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N N N N N
Valeraldehyde (110-62-3)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC NC NC NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC 0.803 NC NC	NIOSH: The recommended airborne exposure limit is 50 ppm averaged over a 10-h workshift ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workshift	N N
Naphthalene (91-20-3)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC <RL <RL 0.0020	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC <RL <RL <RL	NIOSH: The REL is 10 ppm averaged over a 10-h workshift, not to exceed 15 ppm during any 15-min work period OSHA: 10 ppm averaged over an 8-h workday and a 15-minute STEL of 15 ppm ACGIH: The TLV®-TWA for 8-h is 2 ppm	N N N
Pyrene (129-00-0)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC <RL <RL NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	NC 0.0007 <RL <RL	NIOSH: The REL is 0.1 mg/m³ averaged over a 10-h workday (applies to coal tar pitch volatiles) OSHA: The PEL is 0.2 mg/m³ (Coal Tar Pitch Volatiles – as the Benzene soluble fraction)) averaged over an 8-h workshift ACGIH: The TLV®-TWA is 0.2 mg/m³ (Coal Tar Pitch Volatiles – as the Benzene soluble aerosol) averaged over an 8-h workshift	N N N
Methyl ethyl ketone (78-93-3)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	0.184 0.451 2.83 NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC converter (Exit) ---------- Pack Exit	0.175 0.342 1.34 1.05	NIOSH: The REL is 200 ppm averaged over a 10-h workday, and 300 ppm as a short-term exposure limit (STEL) not to be exceeded during any 15-min work period OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended exposure limit is 200 ppm averaged over an 8-h workday, and 300 ppm as a STEL EPA AEGL-1: 200 ppm over 8 h	N N N N
Tetrahydrofuran (109-99-9)	NC	NC	NC	NC	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC	<RL <RL <RL	Ambient Air (APU inlet) ---------- Ozone/ VOC converter (Inlet) ---------- Ozone/ VOC	<RL <RL 0.200	NIOSH: The REL is 200 ppm averaged over a 10-h workday and 250 ppm as a STEL OSHA: The PEL is 200 ppm averaged over an 8-h workday ACGIH: The recommended airborne exposure limit is 50 ppm averaged over an 8-h workday and 100 ppm as a STEL	N N N

					converter (Exit) --- Pack Exit	NC	converter (Exit) --- Pack Exit	0.194		
2-Hexanone (591-78-6)	NC	NC	NC	NC	Ambient Air (APU inlet) --- Ozone/ VOC converter (Inlet) --- Ozone/ VOC converter (Exit) --- Pack Exit	<RL <RL 0.340 NC	Ambient Air (APU inlet) --- Ozone/ VOC converter (Inlet) --- Ozone/ VOC converter (Exit) --- Pack Exit	<RL <RL 0.292 0.263	NIOSH: The REL is 1 ppm as a TWA over 10 h OSHA: The PEL is 100 ppm averaged over an 8-h workshift	N N
Chlorobenzene (108-90-7)	NC	NC	NC	NC	Ambient Air (APU inlet) --- Ozone/ VOC converter (Inlet) --- Ozone/ VOC converter (Exit) --- Pack Exit	<RL <RL <RL NC	Ambient Air (APU inlet) --- Ozone/ VOC converter (Inlet) --- Ozone/ VOC converter (Exit) --- Pack Exit	<RL <RL 0.187 0.171	NIOSH: The REL is 75 ppm averaged over a 10-h workshift OSHA: The PEL is 75 ppm averaged over an 8-h workshift ACGIH: The threshold limit value (TLV®-TWA) is 10 ppm averaged over an 8-h workshift EPA AEGL-1: 10 ppm over 8 h	N N N N
Nonane (111-84-2)	NC	NC	NC	NC	Ambient Air (APU inlet) --- Ozone/ VOC converter (Inlet) --- Ozone/ VOC converter (Exit) --- Pack Exit	0.238 <RL <RL NC	Ambient Air (APU inlet) --- Ozone/ VOC converter (Inlet) --- Ozone/ VOC converter (Exit) --- Pack Exit	0.232 <RL <RL <RL	NIOSH: 200 ppm averaged over a 10-h workshift ACGIH: 200 ppm averaged over an 8-h workshift	N N

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<RL – Below Reporting Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data presented in Table 20 did not reveal exceedances of recommendations, limits, values or guidelines for any of the chemical compounds identified following the injection of Skydrol PE-5 into the APU for the on aircraft test.

Table 21: Summary of Tentatively Identified VOCs and concentrations identified following injection Skydrol PE-5 into the APU (On Aircraft Test), exposure limit/guideline(s) and determination as to if the levels exceed the specified limit/guideline. (Data from Naval Air Warfare Center Aircraft Division)

	Concentration (ppbV; toluene-equivalent)		
Compound (CAS #)	**180°C**	**Exposure Limit/Guideline (GL)**	**Exceeds Exposure Limit/GL (Y/N)**
Isobutylene (115-11-7)	65.9	ACGIH: The TLV®-TWA is 250 ppm for butenes for 8 h	N
Cis-2-butene (624-64-6)	16.0	ACGIH: The TLV®-TWA is 250 ppm for butenes for 8 h	N
Trans-2-butene (590-18-1)	15.6	ACGIH: The TLV®-TWA is 250 ppm for butenes for 8 h	N
Acetone (67-64-1)	1.3	NIOSH: The REL is 250 ppm averaged over a 10-h workshift OSHA: The PEL is 1,000 ppm averaged over an 8-h workshift ACGIH: The threshold limit value-time weighted average (TLV®-TWA) concentration is 250 ppm; the short-term exposure limit (STEL) is 500 ppm EPA AEGL-1 (interim): 200 ppm over 8 h	N N N N
Methacrolein (78-85-3)	1.3	DOE/SCAPA PAC-1: 0.20 ppm	N
Butanal (123-72-8)	13.7	OARS WEEL: RECOMMENDED in 2014 - An 8-h time-weighted average (TWA) of 25 ppm	N

Acetic acid (64-19-7)	4.5	NIOSH: The REL is 10 ppm averaged over a 10-h workshift, not to exceed 15 ppm during any 15-min work period OSHA: The PEL is 10 ppm over an 8-h workshift ACGIH: The TLV®-TWA is 10 ppm for an 8-h workday, and 15 ppm for periods not exceeding 15 min	N N N
1-Butanol (71-36-3)	34.5	NIOSH: The REL is 50 ppm, not be exceeded at any time OSHA: The PEL is 100 ppm averaged over an 8-h workshift ACGIH: The threshold limit value (TLV®) is 20 ppm, not be exceeded at any time	N N N
Phenol (108-95-2)	8.5	NIOSH: The REL is 5 ppm averaged over a 10-h workshift, not to be exceed 15.6 ppm during any 15-min work period OSHA: The PEL is 5 ppm averaged over an 8-h workday ACGIH: The TLV®-TWA is 5 ppm averaged over an 8-h work shift EPA AEGL-1: 6.3 ppm over 8 h	N N N N
2-Ethylhexanol (104-76-7)	7.7	DOE/SCAPA PAC-1: 0.1 ppm	N
2,6-Di-tert-butylbenzoquinone (719-22-2)	3.4	N/A	N/A
Triisobutyl phosphate (126-71-06)	58.5	N/A	N/A
Butylated Hydroxytoluene (128-37-0)	6.3	NIOSH: Recommended 10 mg/m^3 time-weighted average (TWA) airborne exposure limit over a 10-h workshift OSHA: Exposure limit is 10 mg/m^3 as a time-weighted average (TWA) over 8 h ACGIH: TWA exposure limit 2 mg/m^3	N N N
Tributyl phosphate (126-73-8)	197.1	NIOSH: 0.2 ppm over a period of 10-h during a 40-hour work week OSHA: The permissible exposure limit (PEL) is 0.46 ppm (5 mg/m^3) averaged over an 8-h workshift ACGIH: 0.2 ppm averaged over 8 h	N N N
2-Ethylhexyl benzoate (5444-75-7)	7.4	N/A	N/A
2-Cyclopentylproprionic acid, 2-ethylhexyl ester (1000293-47-0)	13.2	N/A	N/A
2-Cyclopentylproprionic acid, 2-ethylhexyl ester (1000293-47-0)	8.7	N/A	N/A

* Value exceeds a given exposure limit/guideline
NC – Not collected, not reported or otherwise not specified
N/A – Not available
<DL – Below Detection Limit
ppb – Parts per billion (=0.001 ppm)
ppbV – Parts per billion by volume
ppm – Parts per million (= 1,000 ppb)

The data from Naval Air Warfare Center Aircraft Division shown in Table 21 did not reveal exceedances of recommendations, limits, values or guidelines for any of the chemical compounds identified following the injection of Skydrol PE-5 hydraulic fluid into the APU for the on aircraft test.

DISCUSSION

This study was designed to assess engine bleed air for chemical contaminants following engine fluid contamination events and evaluate the potential risks for health-related effects should human exposure occur at those levels. Contamination events were simulated by injecting a variety of aircraft fluids, including oils, hydraulic fluids and a deicing fluid into an engine (for off aircraft engine stand tests) or a propulsion engine or APU (for on aircraft tests). A vast variety of chemical compounds were identified across the study, including VOCs, carbonyls and organophosphates. Interestingly, despite the study simulating contamination events by actively injecting aircraft fluids, the chemical compounds were identified at relatively low concentrations – on the order of parts per billion (ppb) or less – with none reaching the level of parts per million (ppm) at which many exposure recommendations, limits and guidelines start to restrict exposure.

Throughout the course of the study, only two chemical compounds exceeded established or published exposure recommendations, limits and/or guidelines – tridecane exceeded its PAC-1 value in one scenario (see Table 4 for engine stand test data for Mobil Jet Oil II) and formaldehyde exceeded NIOSH's *recommended* exposure limit in five scenarios. These five scenarios for formaldehyde involved Eastman Turbo Oil 2389, Mobil Jet Oil II and HyJet IV-A hydraulic fluid in engine stand tests, and Mobil Jet Oil II and Eastman Turbo Oil 2187 in on aircraft tests (see Tables 1, 3, 7, 16 and 18 for details).

As reported in Table 4, tridecane (CAS # 629-50-5) was measured at a concentration of 14.86 ppbV that exceeds the PAC-1 value of 0.0073 ppm (7.3 ppb). However, it should be noted that no technical basis was described for the generation of this low PAC-1 value and therefore it is unclear if this value is scientifically justified. No other published recommendations, limits or guidelines were found for tridecane. Tridecane has been implicated in dermal irritation (Muhammad et al., 2005).

With regard to formaldehyde, despite it technically exceeding NIOSH's REL in five scenarios, with the concentrations ranging from 17-98 ppbV, several considerations should be kept in mind. First, these values only exceed NIOSH's REL if they are maintained at an average greater than 16 ppb for over a period of 10 hours. In other words, if they average to <16 ppb over a period of 10 hours, or do not exceed 100 ppb during any 15-min period, they are not in exceedance of NIOSH's REL. Second, NIOSH's REL is a *recommendation* only and, while it can most certainly be used as guidance, is not an enforceable limit until/unless it is accepted by OSHA as a permissible exposure limit (PEL). Third, OSHA's current legally enforceable PEL is 0.75 ppm (750 ppb) averaged over a period of 8 hours, a concentration nearly 50x greater than NIOSH's recommended 10-hour average and 7.5x higher than the highest concentration identified within this study. The values reported in this study would not be on track to exceed OSHA's 750 ppb 8-hour PEL, nor would they be close to exceeding OSHA's 2 ppm (2,000 ppb) 15-minute short-term exposure limit (STEL) for formaldehyde. Fourth, EPA's interim AEGL-1 level for formaldehyde describes a guideline value at 0.90 ppm (900 ppb) over 8 hours, which the values reported in this study are also far below.

Breathing formaldehyde concentrations as low as 0.1 to 0.5 ppm (100 to 500 ppb) has been reported to result nasal and eye irritation, neurological effects, and increased risk of asthma and/or allergy (ATSDR). Eczema and alterations in lung function have been found to occur at concentrations of 0.6 to 1.9 ppm (600 to 1,900 ppb). As far as whether formaldehyde is likely to cause short- or long-term health effects at the levels detected within this study, which were all below 100 ppb, it has been suggested that using a weight-of-evidence approach for formaldehyde exposure would recommend an indoor air limit of 0.1 ppm (100 ppb), presumably under continuous exposure. This recommended 100 ppb value should protect even susceptible individuals from both irritation and additional, potentially more severe, effects (Golden, 2011). Given that even 100 ppb would be protective for susceptible individuals, it is unlikely that higher levels of formaldehyde reported here (i.e., 17-98 ppbV) would result in adverse health effects.

It is pertinent to mention the levels of formaldehyde that can typically be found, both indoors and outdoors, for comparison to those measured within this study. According to the Agency for Toxic

Substances and Disease Registry, higher concentrations of formaldehyde are typically found in indoor air versus outdoor air and the levels of formaldehyde in indoor air ranges from 0.02 to 4 ppm (equivalent of 20 to 4,000 ppb) while outdoor air levels range from 0.0002 to 0.006 ppm (0.2 to 6 ppb) in rural and suburban areas and 0.001 to 0.02 ppm (1 to 20 ppb) in urban areas. Given this, the concentrations of formaldehyde reported in this study, even with the simulated contamination events, are within or lower than the range of formaldehyde concentrations typically found in indoor air and, to some extent, outdoor air. This is relevant given that if/when formaldehyde is found in aircraft environments, outdoor air cannot be ruled out as a source of the formaldehyde, as opposed to assuming contamination by an aircraft fluid such as oil or hydraulic fluid has occurred.

In sum, while many chemical compounds were identified and quantified over the course of this study, the reported concentrations were remarkably low, typically <100 ppb. Only two compounds, tridecane and formaldehyde, exceeded their published recommendations, limits or guidelines, as described in detail above. All other compounds for which established or published recommendations, limits or guidelines exist were well within acceptable concentrations with regard to anticipated exposure-related health effects.

ABBREVIATIONS

Abbreviation	Definition
µg/m^3	Micrograms per cubic meter
ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	Acute Exposure Guideline Level
AIHA	American Industrial Hygiene Association
APU	Auxiliary Power Unit
ATSDR	Agency for Toxic Substances and Disease Registry
CAMI	Civil Aerospace Medical Institute
CAS #	Chemical Abstracts Service Registry Number
<DL	Below Detection Limit
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
mg/m^3	Milligrams per cubic meter
NIOSH	National Institute for Occupational Safety and Health
OARS	Occupational Alliance for Risk Science
OSHA	Occupational Safety and Health Administration
PAC	Protective Action Criteria
PEL	Permissible Exposure Limit
ppb	Part(s) per billion
ppbV	Part(s) per billion by volume
ppm	Part(s) per million
ppmW	Part(s) per million by weight
REL	Recommended Exposure Limit
<RL	Below Reporting Limit
SCAPA	Subcommittee on Consequence Assessment and Protective Actions
STEL	Short-Term Exposure Limit
TLV®	Threshold Limit Value®
TWA	Time-Weighted Average
VOCs	Volatile Organic Compounds
WEEL	Workplace Environmental Exposure Level

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR), Division of Toxicology and Human Health Sciences: Formaldehyde - ToxFAQs™ and Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological Profile for Formaldehyde. Addendum to the Profile for Formaldehyde. 2010. Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

Chaturvedi AK. Aerospace toxicology overview: Aerial application and cabin air quality. *Rev Environ Contam Toxicol.* 2011; 214:15-40. doi: 10.1007/978-1-4614-0668-6_2.

Chen R, Fang L, Liu J, Herbig B, Norrefeldt V, Mayer F, Fox R, Wargocki P. Cabin air quality on non-smoking commercial flights: A review of published data on airborne pollutants. *Indoor Air.* 2021 Jul;31(4):926-957. doi: 10.1111/ina.12831. Epub 2021 Apr 24. Erratum in: Indoor Air. 2022 Jan;32(1):e12977. Erratum in: Indoor Air. 2022 Oct;32(10):e13152.

Golden R. Identifying an indoor air exposure limit for formaldehyde considering both irritation and cancer hazards. *Crit Rev Toxicol*. 2011;41(8):672-721. doi:10.3109/10408444.2011.573467

Hayes K, Megson D, Doyle A, O'Sullivan G. Occupational risk of organophosphates and other chemical and radiative exposure in the aircraft cabin: A systematic review. *Sci Total Environ*. 2021; 796:148742. doi:10.1016/j.scitotenv. 2021.148742

Muhammad F, Monteiro-Riviere NA, Riviere JE. Comparative in vivo toxicity of topical JP-8 jet fuel and its individual hydrocarbon components: identification of tridecane and tetradecane as key constituents responsible for dermal irritation. *Toxicol Pathol*. 2005;33(2):258-266. doi:10.1080/01926230590908222

National Center for Biotechnology Information (NCBI). PubChem Compound Summary for CID 12388, Tridecane. https://pubchem.ncbi.nlm.nih.gov/compound/Tridecane. Accessed Oct. 1, 2024.