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Aviation Research Division
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Aircraft Air Quality and Bleed Air Contamination Detection: Engine Stand Tests, Sensor Technologies and Chemical Sampling (Phase 2, Volume 1)

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16. Abstract

The purpose of this project was to provide a data-driven process to identify sensing technology with good potential for detecting bleed air contamination from engine oil, hydraulic fluid, or deicing fluid. An on-wing test was conducted in February 2022. A test on an engine test bed was conducted in May 2022. Sensors and instruments were identified, and a test plan was developed. Testing was conducted over a period of approximately one week. Results from this test with respect to sensor ability to detect bleed air contaminants was used on-wing tests performed in 2023. Data analysis for the testing in 2023 is ongoing and will appear in a separate report. Key objectives of the project are to identify sensors and sensor technology with the potential to detect one or more of the three aforementioned bleed air contaminants. Supporting data for this report can be accessed with the following link: https://doi.org/10.21949/1528260.

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Contents

Figures

Tables

Acronyms

Acronym	Definition
APS	Aerosol Particle Sizer
APU	Auxiliary Power Unit
CAMI	Civil Aerospace Medical Institute
CCC	Pack full cold
CO	Carbon Monoxide
cSt	Centistoke
DNPH	Dinitrophenyl hydrazine
EASA	European Aviation Safety Agency
ECS	Environmental Control System
EPA	United States Environmental Protection Agency
eV	Electron Volt
FAA	Federal Aviation Administration
GC/MS	Gas Chromatography Mass Spectroscopy
HHH	Pack full hot
HOL	Human Olfactory Level
HP	High Pressure
ICE	Internal Combustion Engine
MDL	Minimum Detection Limits
MOS	Metal Oxide Sensor
m/z	Mass divided by charge for Mass Spectroscopy
NAWCAD	Naval Air Warfare Center Aircraft Division
NNN	Pack at normal operating temperature
NOx	Oxides of Nitrogen
PAH	Polycyclic aromatic hydrocarbons
PID	Photoionization Detector
PM	Particulate matter
PN	Part Number
ppbV	Parts per billion by Volume
PSI	Pounds per square inch
PUF	Polyurethane foam
SCFM	Standard cubic feet per minute
SLPM	Standard Liters Per Minute

Acronym	**Definition**
SMPS	Scanning Mobility Particle Sizer
SN	Serial Number
SVOC	Semivolatile Organic Compounds
TBP	Tributyl Phosphate Isomers
TCP	Tricresyl Phosphate Isomers
TICS	Tentatively Identified Compounds
TO	Toxic Organic
TPP	Triphenyl Phosphate Isomers
TSI	Thermo-Systems Engineering Company Incorporated
TSN	Time Since New
UFP	Ultrafine particle
VOC	Volatile Organic Compounds
XAD®	Adsorbent hydrophobic organic porous polymer

Executive Summary

The FAA Reauthorization Act of 2018, Section 326, Aircraft Air Quality, subsection (C)(1) directed the Federal Aviation Administration (FAA) to commission a study with the following objectives:

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 (Congress, 2018).

The Phase 1 Kansas State University (KSU) research project addressed item one in the list above (Jones, 2022). The Phase 2 KSU research project focused on items 3 and 4 in the list above and assisted the FAA's Civil Aerospace Medical Institute (CAMI) to perform item 2 above by collecting laboratory samples and sending them to outside laboratories for analysis. The analysis of laboratory chemical data to assess health effects was beyond the scope of the KSU contract, and the FAA/CAMI performed the health effects assessment independently in collaboration with two U.S. Navy Commands – the Naval Air Warfare Center Aircraft Division for independent chemical sampling and analysis and the Naval Medical Research Unit Dayton for toxicological analysis and interpretation. The separate, independent Navy reports and datasets are available at: https://doi.org/10.21949/1529639.

This report, which builds on Jones (2022) provides information to the FAA, which identifies currently available technologies that could be adapted to monitor aircraft supply system contamination while the aircraft is in flight. Some instruments utilized during the testing may not be considered practical for utilization in flight for a variety of reasons, such as the need for an operator to be present to obtain samples and monitor the instrument, high power consumption, or the requirement to replenish fluids every few hours of operation. Some of these less-practical instruments for in-flight utilization, however, provide high quality data that helped the research team better identify the influence of system components on the condensing contaminants and their release when engine or air conditioning systems change. It was believed formerly that

contamination was produced in the engine and passed directly through the air conditioning system to the aircraft cabin. This study has demonstrated that other locations in the air conditioning system can cause contaminants to condense and then be re-entrained later when proper conditions cause their release. This study recommends that bleed air contaminants be measured in multiple locations in the bleed system, and not within the cabin when assessing the presence of bleed air contaminants. Residence times may be too short for some sensors, and some could be useful for detection of supply system contamination in the cabin or return air to the mix manifold. The next series of Phase 2 testing during the on-wing portion of the research may provide further information on sensor detection capability when utilized on-wing. Ultrafine particle (UFP) measurements and spectrometer measurements were the most successful methods for detecting the presence of contaminants. Other measurements such as carbon dioxide measurement aid in screening out engine exhaust ingestion. This study found that carbon monoxide (CO) is not produced at levels above 1 ppmV for the KSU Allison 250 C28B test engine at bleed air temperatures in the normal operating range of 200℃ to 260℃. Supporting data for this report can be accessed with the following link: https://doi.org/10.21949/1528260.

1 Introduction

The FAA Reauthorization Act of 2018 (Congress, 2018), in Section 326, Aircraft Air Quality, subsection (C)(1) directed the Federal Aviation Administration (FAA) to commission a study with the following objectives:

1. 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. Assess the potential health effects of such constituents on passengers and cabin and flight deck crew.
3. 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.
4. Identify potential techniques to prevent fume events.

The Phase 1 Kansas State University (KSU) research project which addressed item one in the list above (Jones, 2022), conducted a literature review, and preliminary auxiliary power unit (APU) and engine tests.

This project consists of two parts, (1) to assess the capability of current, commercial off-the-shelf sensors to detect bleed air contaminants resulting from engine oil, hydraulic fluid, and deicing fluid, and (2) the collection and chemical analysis of engine bleed air contaminants resulting from engine oil, hydraulic fluid, and deicing fluid. Engine stand test data and results were used to inform and further refine test plan development for the follow-up on-aircraft tests. The aircraft test results will be published in a separate volume once the on-wing testing has been completed and the data analyzed. Supporting data for this report can be accessed in the accompanying dataset (KSU, 2024).

2 Methods

2.1 Test setup/layout

A schematic diagram of the engine with contaminant injection location and sampling points is presented in Figure 1. This schematic diagram introduces the reader to the basic elements of the test setup. An engine was utilized to produce a bleed air sample. Contaminant (Appendix A) was introduced into the engine, and samples were conducted from the intake air and from the bleed air to sample real time instruments and laboratory chemical samplers. A detailed test instrument plumbing schematic diagram is depicted in Figure 2. The detailed plumbing schematic is simplified for viewing. Each instrument, other than diffusion type sensors, were plumbed with refrigeration grade copper tubing,

The plumbing system was designed to provide a continuous positive pressure to all samplers. The challenge in sampling is to be able to supply the high volume required by the Tisch high volume sample trains (250-300 liters per minute), while maintaining sufficient positive flow to all analyzers and sampling systems. A system was created for the bleed sample line by venting the bleed air manifold into a cylinder fabricated with 4-inch diameter PVC. A ¾ inch tube was inserted into the cylinder, which was open on the top. Water could be poured into the top of the cylinder, and a valve at the bottom permitted the water to be drained. Maintaining a head of 2 to 3 inches of water ensured a slight positive pressure to all sample lines. The high-volume sample train was connected to the ½ inch stainless steel sample line through a tee fitting and then connected to ¾ inch vinyl tubing to permit removal and installation of the sample train.

The inlet sample supply was self-limited by the design of the centrifugal supply blower. The blower can only build up a small amount of total air pressure in the duct. The 3-inch duct was adapted down to a ½ inch stainless steel bulkhead fitting for the sample distribution manifold. This restriction proved to be adequate to maintain a small positive pressure on the intake sample manifold. The high-volume sampler also had sufficient flow. The 3-inch blower duct was connected to a 3-inch diameter aluminum flex duct to allow removal of the sampling train. Three supply lines with carbon loaded silicon tubing were installed on the bleed air diffusion sample box (Menards “Masterforce 21” Suitecase Toolbox) and two lines on the diffusion sample box (Similar to Pelican 1300 Protector Case) to reduce response times of the diffusion samplers. Pass through holes that permitted electrical cables and connectors to feed signals from the instruments and power to the instruments permitted the volume of the interior of the diffusion sample box.

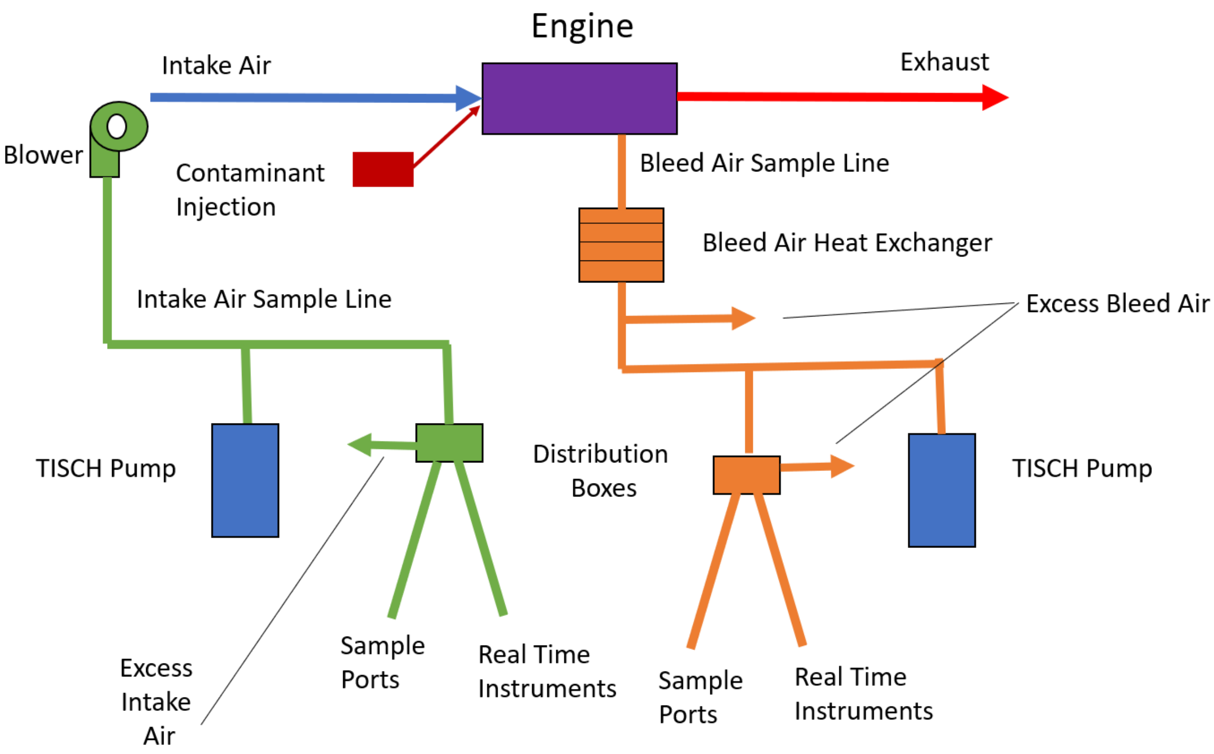


Figure 1. Sampling location schematic

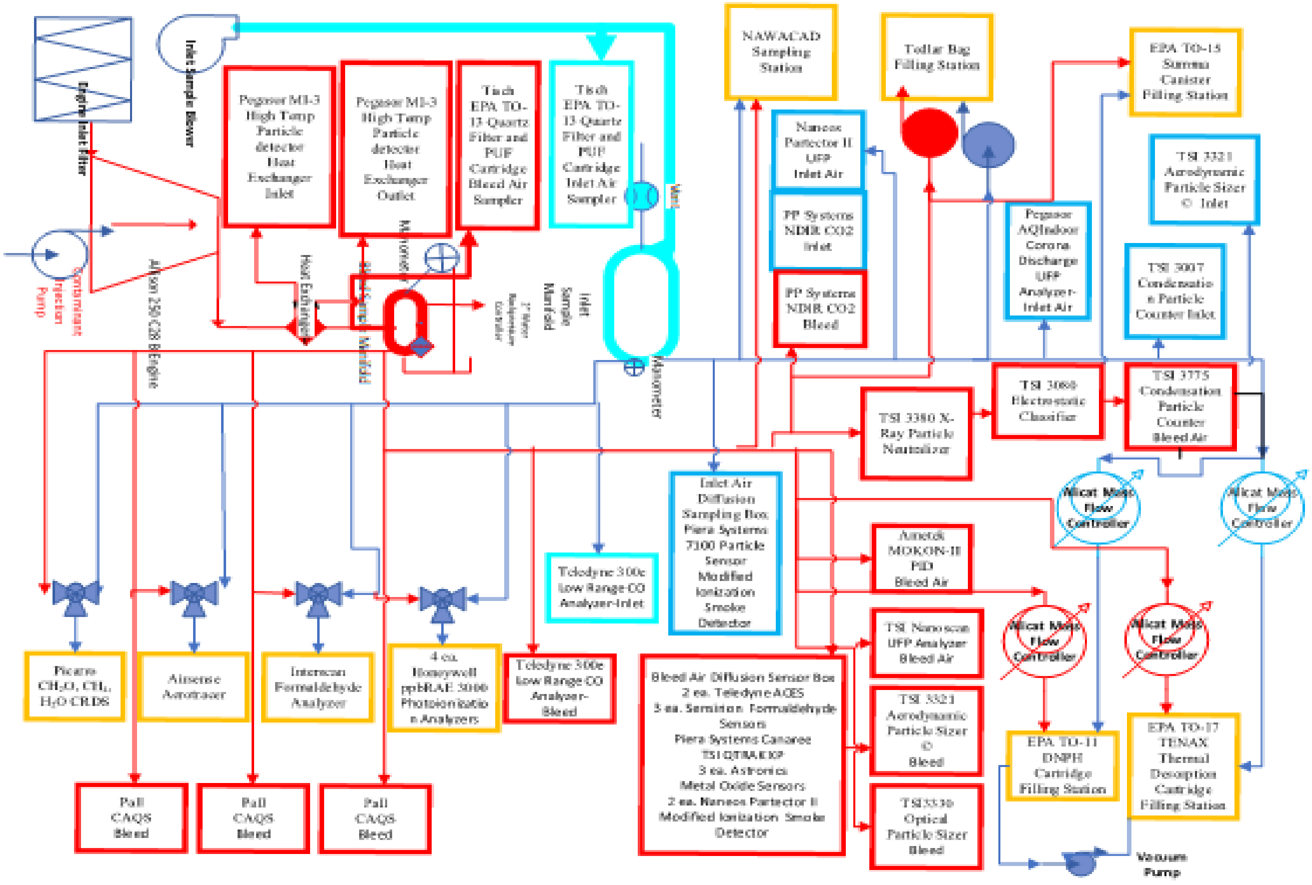


Figure 2.Test instrument schematic diagram

Key: Bleed air sample- Red; Engine inlet air- Blue; Sample for inlet & bleed- Gold

2.1.1 Engine description

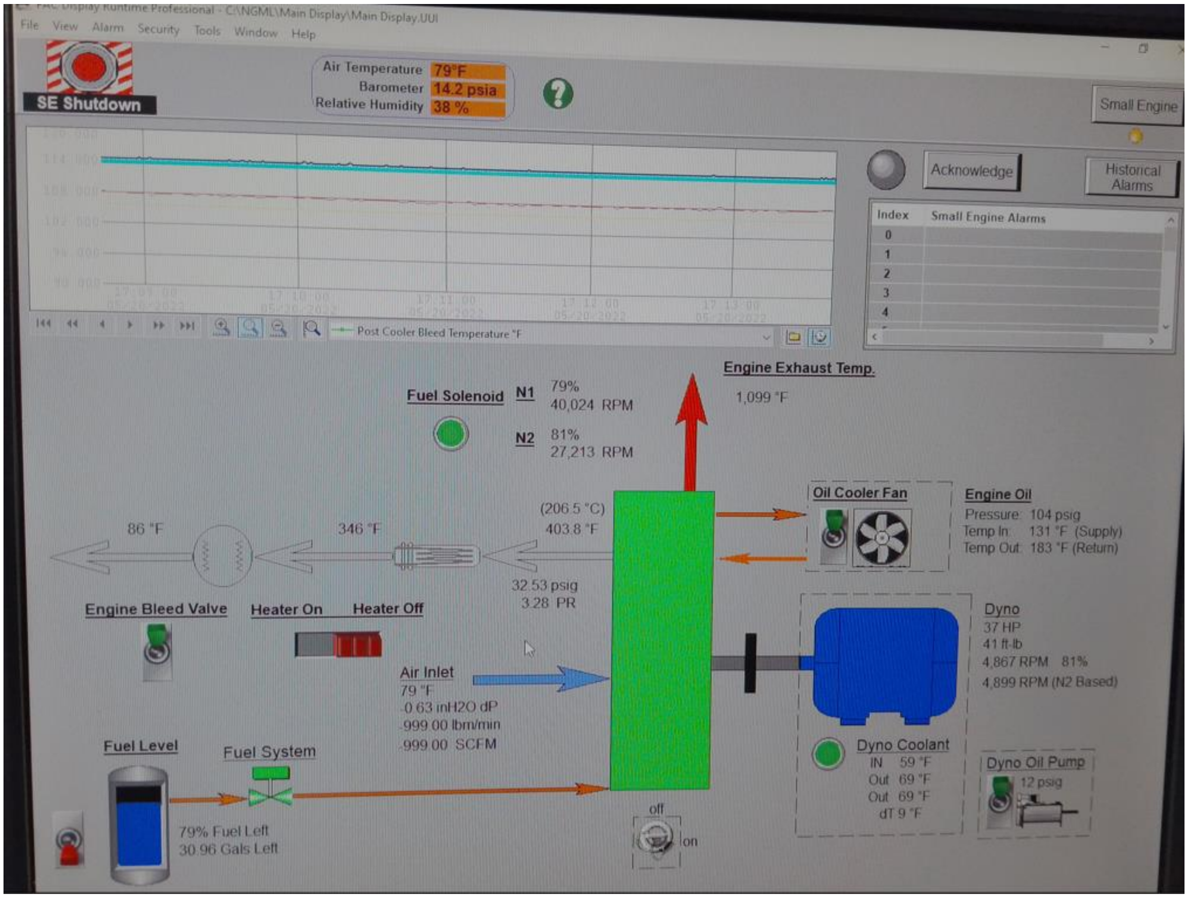
The 500 shaft-horsepower Allison 250-C28B engine is a turboshaft engine that was designed for helicopter applications. The unit used for the KSU test had been overhauled and tested prior to being shipped to KSU for setup on its engine testbed.

The engine gearbox, with a maximum output shaft speed of 6000 rotations per minute, is connected to a General Electric Model 1G35 Inductor Dynamometer (Serial Number 6842177), which provides the necessary shaft loading of the engine. Two control modules used to control the engine and the dynamometer include Dyne Systems Model OECPAU015RS-GC Control Module Serial No. SN2599, and Dyne Systems Model OIL5-OCS-04 Control Module Serial No. SN2602.

The engine was connected to a General Electric Model 1G335 600 HP Inductor Dynamometer to provide a load and allow the engine operating condition to be controlled. The dynamometer is controlled by Dyne Systems electronic controllers, Model S OECPAU015RS-GG and OIL-OCS-04 (Figure 3) The dynamometer controller is an engine safety mechanism that automates the loading of the engine and prevents dangerous operating conditions such as engine overspeed.

Figure 3. Engine and dynamometer control panels

An image of the Graphic User Interface (GUI) is presented in Figure 4. The GUI allows the engine operator to monitor the system temperatures and pressures of the engine and bleed air-cooling.



Air Temperature 79°F
Barometer 14.2 psia
Relative Humidity 38 %

N1 79% 40,024 RPM
N2 81% 27,213 RPM

Engine Exhaust Temp.
1,099 °F

86 °F
346 °F
(206.5 °C) 403.8 °F
32.53 psig
3.28 PR

Engine Oil
Pressure: 104 psig
Temp In: 131 °F (Supply)
Temp Out: 183 °F (Return)

Dyno
37 HP
41 ft-lb
4,867 RPM 81%
4,899 RPM (N2 Based)

Air Inlet
79 °F
-0.63 inH2O dP
-999.00 lbm/min
-999.00 SCFM

Dyno Coolant
IN 59 °F
Out 69 °F
Out 69 °F
dT 9 °F

Dyno Oil Pump
12 psig

79% Fuel Left
30.96 Gals Left

Figure 4. Engine system graphic user interface

2.1.2 Inlet air system

2.1.2.1 Inlet filters

The engine intake air is filtered through two particulate filters to remove atmospheric dust (Figure 5). The air then passes through a steel duct to an inlet air box mounted onto the engine inlet.

Figure 5. Dual inlet air filters (upper red circle) and inlet air sample (enclosed within lower left circle)

2.1.2.2 Engine inlet mass airflow determination

Airflow is measured by a Dwyer Series 424 FLST flow meter (Figure 6) mounted in 12-inch round inlet air duct. It is mounted away from any bends or obstructions in accordance with factor specifications. The accuracy specifications for the mounted flow meter are ±2%.


Figure 6. Dwyer Series 424 stationary gage flowmeter

This flow meter determines flow rate by measuring the difference between static and stagnation pressure like a Pitot tube except it has a built-in averaging feature to get the average for the whole cross-section of flow.

The average flow velocity is calculated according to the Bernoulli relationship:

$$\Delta P = 0.5 \rho V^2 \qquad 1$$

where:

ΔP is the measured pressure difference (N/m^2)
ρ is the air density at the flow meter (kg/m^3)
V is the averaged air speed (m/s)

The mass flow is determined from the continuity equation:

$$m = \rho V A \qquad 2$$

where:

m is the mass flow (kg/s)
A is the area of the duct (m^2)

Combining equations 1 and 2 and solving for the mass flow gives:

$$m = A (2 \rho \Delta P)^{1/2} \qquad 3$$

The duct diameter, D, is 0.3048 m (12in) which gives an area of:

$$A = (\pi/4) D^2 = 0.07297 \text{ m}^2 \qquad 4$$

The density can be evaluated using the ideal gas equation:

$$\rho = P W/(R T) \qquad 5$$

where:

P is the absolute pressure (N/m^2)
W is the molecular weight of the air going through the meter (kg/kmol)
R is the universal gas constant, (8314 N-m/kmol-K)
T is the absolute temperature (K)

The molecular weight of air varies slightly with moisture content. A value of 28.92 kg/kmol will be accurate to within 0.25% over the range of humidity encountered during the testing and it can be treated as constant at this value. The temperature will vary some so the actual temperature at the time of measurement should be used. If it is within 3 degrees, it will be accurate with 1%. The pressure will also vary and the atmospheric pressure at the time of measure should be used. Additionally, the pressure drop through the inlet filters will lower the pressure at the meter and should be reflected in the calculation.

This loss can be estimated by:

$$L = 78 \text{ x m} \qquad 6$$

where L is the pressure loss (N/m^2), and the mass flow is in kg/s.

At a typical mass flow of 1 kg/s, the pressure loss of 78 N/m^2 is less than 0.1% of the atmospheric pressure of approximately $97x10^3$ N/m^2 and can be ignored.

Combining equations 3, 4, and 5 gives:

$$\text{m} = 0.07297\, m^2 \{(2 \text{ P } \Delta\text{P} / \text{T}) \text{ x } [28.92 \text{ kg/kmol} / 8314 \text{ N} - \text{m/kmol} - \text{K}]\}^{1/2} \qquad 7$$

Simplifying gives:

$$\text{m} = 6.086\text{x}10^{-3} (\text{P } \Delta\text{P}/\text{T})^{1/2} \qquad 8$$

where P and ΔP are in N/m^2 and T is in Kelvin.

However, ΔP is measured in inches of H_2O and 1 inch H_2O is 249.1 N/m^2. For ΔP measured in inches of H_2O, the relationship becomes:

$$\text{m} = 0.09606\, (\text{P } \Delta\text{P}/\text{T})^{1/2} \qquad 9$$

Example calculation:

$P = 95.87\ \text{kPa} = 95{,}870\ \text{N/m}^2$

$\Delta P = 0.33$ inches H_2O

$T = 25^{\circ}\text{C} = 298.15\ \text{K}$

$m = 0.09606\ (9.587\text{x}10^4 \text{ x } 0.33 / 300) = 0.986\ \text{kg/s}$

2.1.2.3 Engine inlet sample blower

A centrifugal blower (shown in Figure 5) was used to draw an ambient air sample. The blower, manufactured by Madison Manufacturing Company in Hot Springs, NC, was a model PW11, driven by a 1 HP motor and can deliver up to 786 cubic feet per minute of air (nameplate shown in Figure 7). The blower limitation was that it only produces air movement with low back pressure, so the sample system design did not require dumping large quantities of air from the inlet blower.

MODEL PW11

ORDER 3130

CLASS 1

PART NO. 101114001

RPM 3500

P.O.NO. DH38383680

C.F.M.

SP.

Figure 7. Inlet air sample blower nameplate

2.1.3 Exhaust system

The exhaust system for the test cell was changed to extend the exhaust exit above the roof level to minimize the likelihood of exhaust recirculation. A weather station was also installed several feet from the exhaust stack to monitor wind direction (Figure 8).

Figure 8. Engine exhaust system

2.1.4 Bleed air cooling

A primary heat exchanger designed for a Beechcraft airplane, with the addition of a blower for secondary cooling air flow, was used to reduce bleed air temperature to desired levels (Figure 9). The secondary cooling blower was blocked with a sheet of plywood (shown in Figure 9) during the cleaning cycles to elevate the heat exchanger temperature and volatilize organic material that had condensed on the heat exchanger. These cleaning cycles are noted on data charts following injection of each type of contaminant fluid.

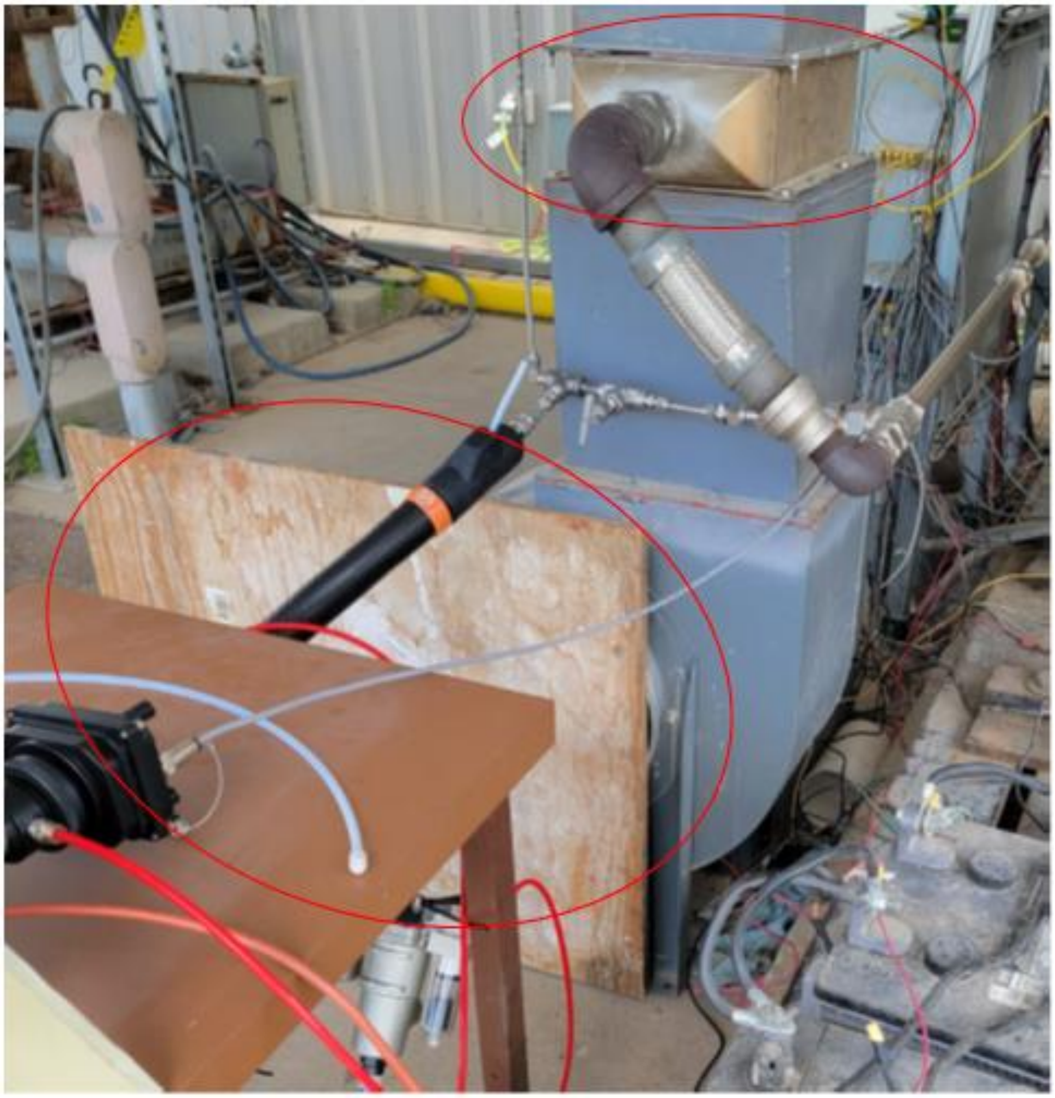


Figure 9. Bleed air cooling (upper red circle) and hot UFP sampling (lower red circle)

2.1.5 Contaminant injection system

A programmable syringe pump, Model BS-300 from Braintree Scientific, Inc. (Figure 10) was programmed to deliver the desired mass flow rate of contaminants to the engine aspiration port, which conducted the contaminant to the engine inlet downstream of the engine inlet particle separator. No correction for dilution of bypass air is required since the entire volume delivered enters the core air stream of the engine. Injection syringes for the syringe pump were ordered from Braintree Scientific, Inc. A 50-cc syringe (Large Syringe Kit Item # P-SYRKIT-LG) from Braintree Scientific) was utilized to reduce the refill frequency to one time per test condition. The flow rate of the injection pump was adjusted based on calculated mass airflow to the engine inlet. The air flow rates are recorded in the daily engine logs (Appendix B). The mass injected per hour is listed in laboratory chemical sample logs for each day of test, located in Appendix E.

Figure 11 shows the external view of the contaminant aspiration probe and the 1/8-inch barbed tee connected to the aspiration probe. Figure 12 shows an internal view of a representative aspiration probe welded to the engine inlet particle separator. The unit in service was welded in place after the welding technique was perfected on a sample inlet. The unit in service was not photographed prior to assembly at the engine overhaul shop.

Figure 10. Contaminant injection syringe pump

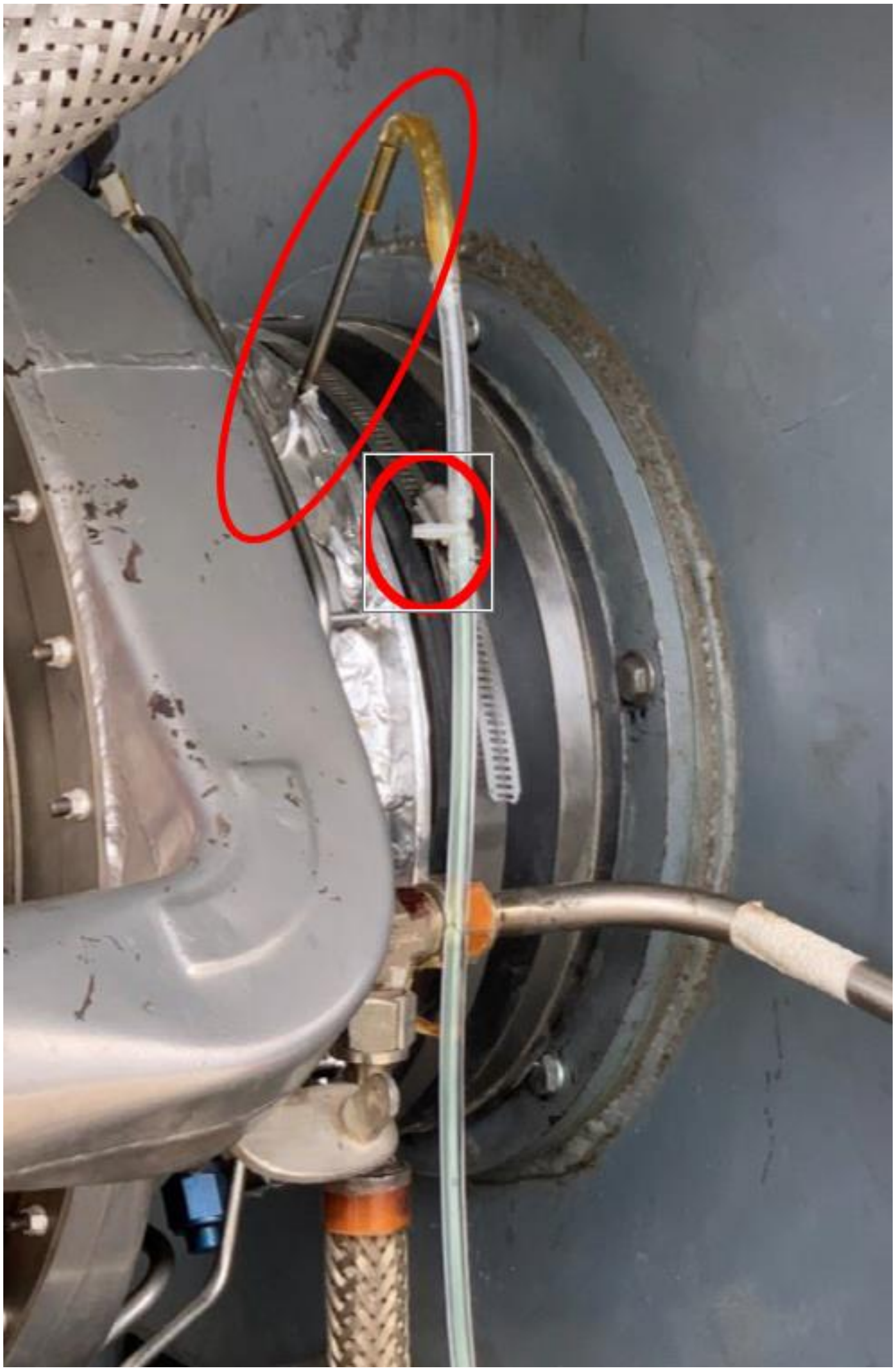


Figure 11. Contaminant aspiration probe (external view)

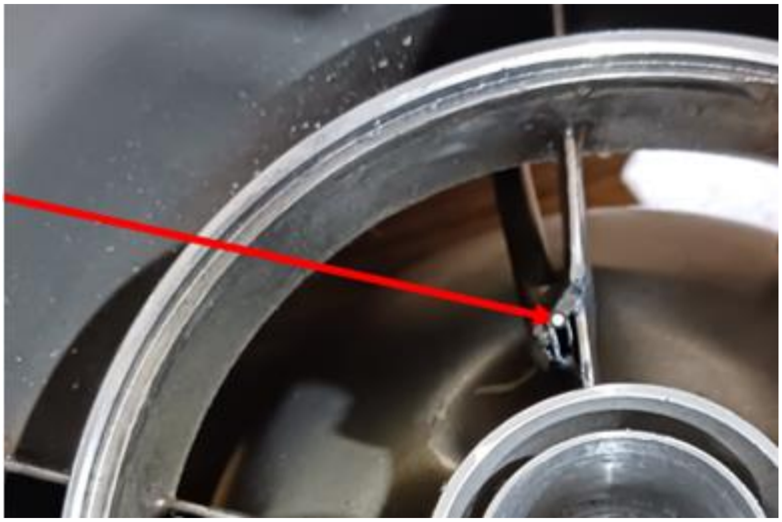


Figure 12. Inlet particle separator with contaminant aspiration probe (internal view)

2.1.5.1 Syringe pump validation

To verify that the syringe pumps used for contaminant injection were supplying accurate delivery of contaminant fluid, a test was conducted. The procedure was as follows.

A syringe of the same make and model as used in the engine experiments was utilized. The same diameter as specified during the experiments was entered into the pump programming. The pumps and a mass balance were allowed to warm up for a minimum of 30 minutes prior to the tests. The tests were conducted at room temperature, approximately 70^{o}F. Prior to the test, the syringe was filled with tap water and care was taken to remove air bubbles from the syringe. A 16-inch length of flexible plastic tubing was connected to the syringe, the same kind of tubing used for contaminant injection. The tubing was filled with water from the syringe and inspected to ensure there were no air bubbles in the tubing. The empty collection cup was weighed immediately prior to starting a test. The pump was started at the test rate and allowed to operate for several minutes. Then, simultaneously, a stop clock was started, a collection cup was positioned to collect the discharged water from the plastic tube, and a total volume reading was taken from the syringe pump. After approximately one hour, the pump was stopped, and the stop clock was read. The collection cup weight was recorded. It was then emptied, dried, and reweighed to verify the empty value was the same as empty value prior to the test.

Because of the one-hour duration of the test, evaporation from the collection cup could be significant. Following the collection test, a small amount of water was placed in the cup, enough to ensure the bottom was completely covered. The cup and water were weighed and then the cup with water was placed at the same location as for the collection test. After approximately one hour, the cup and water were reweighed to determine the amount of evaporation. That amount was adjusted for any difference in the duration of the evaporation test and the collection test and added to the measured discharge amount. The measured mass was converted to volume using the density of water at 70°F, 0.998 g/ml.

The data and calculations for the tests follow in Table 1. It is seen that the deviation between the discharge volume indicated by the pump and the volume measured was less than 1% for both pumps. The syringe pump flow rates were validated post-test in December 2022. The mass balance used for weighing was a Mettler Toledo Model PR8002 with 0.01-gram resolution.

Table 1. Syringe pump validation

Date:	**December 15, 2022**	**December 16, 2022**
Make:	Braintree Scientific	Braintree Scientific
Model:	BS-300	BS-300
SN:	306827	304162
Fluid:	Tap Water	Tap Water
Syringe Diameter:	29.20 mm	29.20 mm
Syringe:	HSW 60 ml	HSW 60 ml
Rate:	25 ml/hr	25 ml/hr
Start Time:	0	0
Start Volume:	31.93 ml	6.70 ml
Start Mass:	0 g	0 g
End Time:	1:00:00	1:03:00
End Volume:	56.93 ml	32.94 ml
End Mass:	24.48 g	25.71 g
Total Volume Delivered:	25.00 ml	26.24 ml
Total Mass Delivered:	24.48 g	25.71g
Water Density:	0.998 g/ml	0.998 g/ml
Calculated Volume Delivered:	24.48 g/(0.998g/ml) =24.53 ml	25.71g /(0.998g/ml) =25.76 ml
Evaporation Test Start:	1:03 PM	12:02 PM
Evaporation Test End:	14:18 PM	13:05 PM
Start Mass:	18.16 g	56.11 g
End Mass:	17.78 g	55.78 g
Total Mass Loss:	0.38 g	0.33 g
Corrected Total mass loss (1-hour):	0.30 g	0.33 g

Date:	**December 15, 2022**	**December 16, 2022**
Corrected mass delivered:	24.48 g + 0.30g=24.78g	25.71 g+ 0.33g = 26.04g
Corrected Volume delivered:	24.78g/(0.998g/ml) = 24.83ml	26.04 g / (0.998g/ml) =26.09 ml
Deviation:	(25-24.83)/25.0-0.0068=0.68%	(26.24 ml-26.09 ml)/26.24 ml=0.0057= 0.57%

2.1.5.2 Uncertainty analysis for mass concentration

The mass concentration, C, of a contaminant is:

$$C = (1x10^{-3}\ \mathrm{L/ml})\ x\ (1\ \mathrm{hr}/3600\ \mathrm{s})\ \rho\ v\ /\ m = 2.778\ x\ 10^{-7}\rho\ v\ /\ m \tag{10}$$

Where:

C is the mass concentration (nd)
ρ is the density of the liquid contaminant injected (kg/L)
v is the volume flow rate of the injected contaminant, ml/hr
m is the engine compressor mass flow (kg/s)

Example calculation:

ρ = 1.00 kg/L
v = 25.0 mL/hr
m = 1.00 kg/s
m= $2.778x10^{-7}$ x 1.00 x 25.0 / 1.00 = 6.06 $x10^{-6}$ = 6.94 ppm

A sensitivity calculation on the above relationship gives:

$$ec = e_{\rho} + e_{v} - e_{m} \tag{11}$$

where:

e_C is the relative error in the mass concentration (nd)
e_ρ is the relative error in the contaminant density (nd)
e_v is the relative error in the contaminant delivery rate (nd)
e_m is the relative error in the engine compressor mass airflow (nd)

Refer to the “Engine Air Mass Flow Determination” document. A sensitivity calculation for “m” gives:

$$e_m = e_A + ½ (e_w + e_P + e_{\Delta P} - e_T) \qquad 12$$

$$e_m = e_A + ½ (e_w + e_P + e_{\Delta P} - e_T) \qquad 13$$

where:

e_m is the uncertainty in the mass airflow (nd)
e_A is the uncertainty in the flow meter area (nd)
e_W is the uncertainty in the air molecular weight (nd)
e_P is the uncertainty in the air pressure at the flow meter (nd)
$e_{\Delta P}$ is the uncertainty in the pressure differential measurement (nd)
e_T is the uncertainty in the absolute temperature of the air going through the flow meter (nd)

Combining equations 2 and 3 and using a root mean square summation since all of the uncertainties are independent gives:

$$e_C = [e_\rho^2 + e_v^2 + e_A^2 + (e_w/2)^2 + (e_P/2)^2 + (e_{\Delta P}/2)^2 + (e_T/2)^2]^{1/2} \qquad 14$$

The density of the contaminant fluid is generally known to several significant figures of accuracy from the Safety Data Sheet (SDS). If not specified in the SDS, it can be measured in the lab easily to within ½% accuracy, so $e_\rho = 0.005$. Per the Syringe Pump Validation document, the validation was accurate to within 0.7% or better, so $e_v = 0.007$. The duct diameter, d, was measured and it is accurate to within 1/8 inch. Thus, $e_d = (1/8)/12 = 0.01$.

The area of the duct is:

$$A = (\pi/4)\, d^2 \qquad 15$$

A sensitivity calculation on this expression gives:

$$e_A = 2\, e_d = 0.02 \qquad 16$$

The molecular weight of the air can be estimated to within 0.25% even when treated as constant. Thus, $e_w = 0.0025$. Ambient pressure was measured during all of the tests and is accurate to within 0.5% or better. The pressure drop through the inlet filters is only estimated and it is believed to be accurate to within a couple of inches of water which works out to be about 0.5% as well. Thus, $e_P = 0.7\%$ using a root mean square combination since the error sources are independent. The ΔP measurement appears to be the largest source of uncertainty. The resolution on the inclined manometer used to measure it is 0.02 inches of H_2O and, even with good technique, the best that can be done is to read it within that resolution. The ΔP values ranged from approximately 0.30 inches to 0.50 inches. Using the lower end, $e_{\Delta P} = 0.02/0.30 = 6.7\%$. The ambient temperature was measured, and the actual temperature measurement is accurate to better than 1^oC. However, temperature gradients and heat loss or gain in the inlet duct could allow the actual temperature at the airflow meter to deviate by several degrees from this value, perhaps a maximum of 3^oC. However, it is the absolute temperature that is important. For a typical absolute temperature of 300K, $e_T = 3/300 = 1.0\ \%$.

Substituting all of these values into equation 4 gives:

$$e_C = 0.037 = 4.0\% \tag{17}$$

If all the other uncertainties were zero, the uncertainty in the ΔP measurement would still result in a 3.4% uncertainty so, as expected, it is clearly the dominant source of uncertainty in the contaminant concentration determination.

2.2 Sample transfer to analytical benches

2.2.1 Bleed air sample system

2.2.1.1 Engine to heat exchanger

The line from the engine bleed ports to the heat exchanger is pictured in Figure 13. The heat exchanger is air cooled with a blower attached below the heat exchanger.

2.2.1.2 Heat exchanger to bleed dump and connection to stainless steel sample line

The line exiting the bleed air heat exchanger is made from steel pipe (Figure 14). The flange located in the center of the line is utilized for an orifice flow meter but could not be utilized for this test since the test plan called for heating the heat exchanger above the safe operating temperature of the flow meter.

Figure 13. Flex line from engine bleed valve to heat exchanger and heat exchanger blower

Figure 14. Bleed air sample line - bleed air heat exchanger to stainless steel sample line

2.2.1.3 Stainless steel sample line to bleed sample distribution manifold

Lines outside the building utilized 0.75-inch diameter stainless steel tubing (Figure 15). The bleed sample line is connected to a manifold (Figure 16).

Figure 15. Bleed air sample line from engine to building

Figure 16. Inlet and bleed air sample manifolds

2.2.1.4 Copper bleed air distribution sample lines from sample manifold to instruments

Refrigeration grade copper tubing (ASTM, 2020) was utilized to route samples to the instruments on the instrument benches from the sample manifolds due to high cost and long delivery time of other types of tubing. The cleanliness requirement of ASTM B280 limits residue within the tubing to no more than 38 mg/m^2 of inner wall area of copper tubing (Cambridge-Lee Industries, LLC. , 2022).

Other types of tubing utilized for instrument connection included ¼ inch carbon loaded Teflon tubing, ¼ and 3/8” carbon loaded silicon tubing, and vinyl tubing (Figure 17). Carbon loaded tubing was utilized for connection of instruments that were measuring ultrafine and fine particles. Flexible silicon tubing was utilized for connecting the diffusion sampler boxes to provide flexibility for opening the box covers.

Figure 17. Copper and carbon loaded silicon sample line tubing bundles

2.2.1.4.1 Copper sample line effect on CO measurement

An experiment was conducted August 3, 2022, in the National Gas Machinery Laboratory (NGML) office area to figure out if sample line material had any influence on carbon monoxide (CO) readings. Two Teledyne Model 300e instruments were used for the measurements, serial numbers 692 and 693. The instruments had been continuously running for several days in a conditioned indoor environment prior to the experiments. Airgas part number X02A199CP104640 carbon monoxide calibration gas (50 ppm CO and 20.9% O2 in nitrogen, +/-2%, expiration 3/26/2026) was used for all measurements. The instruments were zeroed using ambient air prior to the measurements. The span calibration was not adjusted.

The calibration gas bottle was fitted with a demand regulator and the calibration gas was supplied via a tee in the sample line to both instruments simultaneously. The calibration gas was connected directly to the instrument through a short length (~ 3 feet) of vinyl tubing and then connected through 50 feet of stainless-steel tubing, 60 feet of copper tubing, and 50 feet of Teflon tubing. All tubing was nominal ¼ inch outside diameter. In each case the calibration gas was flowed until the concentration readings stabilized. Results are presented in Table 2. The conclusion of this test is that there was slight loss of carbon monoxide in a 50-foot length of copper tubing of around 10 to 50 parts per billion CO. This amount of loss is below the noise level of electrochemical and metal oxide CO sensors. Our conclusion is that the use of refrigeration grade copper tubing as an alternative to Teflon tubing, which cost around $6.00/foot and had an uncertain lead time for delivery, did not adversely affect the measurement results for this set of tests.

Table 2. Effect of copper on CO measurements

Time	**Line**	**SN 692 CO (ppm)**	**SN 693 CO (ppm)**	**SN 692 Flow (mL/min)**	**SN 693 Flow (mL/min)**	**Delta to Direct SN692**	**Delta to Direct SN693**
10:32	Direct #1	50.347	50.465	765	737		
10:35	Direct #2	50.397	50.456	767	737		
10:42	50 ft SS #1	50.526	50.328	760	734	0.179/0.129	-0.137/-0.128
10:44	50 ft SS #2	50.348	50.422	760	734	0.001/-0.049	-0.043/-0.034
10:51	60 ft CU #1	49.799	49.799	758	732	-0.638/-0.598	-0.666/-0.657
10:53	60 ft CU #2	49.861	49.926	758	732		
10:54	60 ft CU #3	49.892	49.913	757	732		
11:00	50 ft PTFE #1	50.485	50.625	728	714		
11:02	50 ft PTFE #2	50.500	50.719	728	714		
11:07	Direct	50.373	50.507	764	736		
11:09	Direct	50.340	50.457	765	735		

2.2.2 Inlet air sample system

2.2.2.1 Duct from blower to sample manifold

The ambient air sample was conducted to the test benches via 3-inch galvanized sheet metal ducting shown in Figure 5.

2.2.2.2 Adapting to sampling distribution and pressure control manifolds

The inlet and bleed air sample lines were connected to the inlet and bleed air manifolds utilizing ½ inch stainless steel tubing and bulkhead fittings. These are pictured in Figure 16.

Inlet and bleed air sample manifold pressures were monitored using two digital manometers connected to fittings on the two manifolds. This is to ensure a small amount of sample pressure was always present at the sample manifold when analyzers, and the high-volume samplers were drawing sample to verify that sufficient flow was always present to prevent backflow of air from the laboratory (Figure 18).

Figure 18. URPRO digital manometers to monitor inlet and bleed sample manifolds

The layout of the analytical test benches is presented in Figure 19. There was approximately 60 lineal feet of bench space that was laid out on a bench level and on a secondary level above the benches. A work area with a big screen monitor displaying the test plan for the day provided space for the team to have work room to manage the number of analyses being performed.

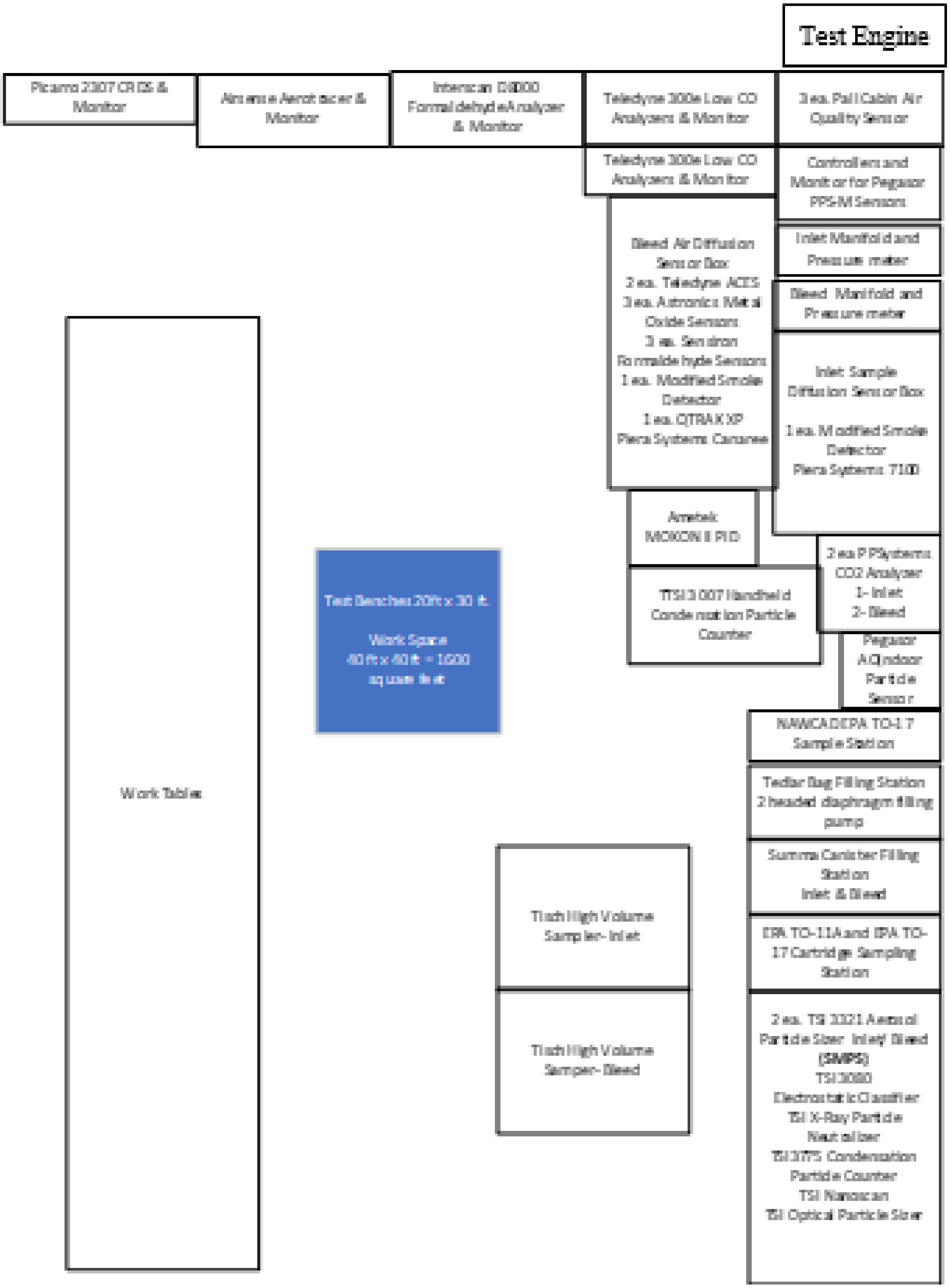


Figure 19. Analytical bench layout

2.2.2.3 Adapting to high volume sample system

Ambient air pesticide samplers from Tisch Environmental were adapted to allow ducting of bleed air from the ½-inch diameter unheated stainless steel bleed air sample line and the 3-inch galvanized duct (Figure 20). Honeywell had found that the inlet end of Staplex® CKHV and CKHV810 Calibration Kits for High Volume Air Samplers could easily be adapted. The 3-inch diameter aluminum cylinder with a flange on one end to seal to the quartz filter inlet has a welded plate on the other end. Honeywell ordered additional parts without the end plate to adapt to 3-inch diameter aluminum flex duct for lower pressure samples. The end cap on the cylinders provided in the calibration kit was drilled out to permit a 3/4-inch barbed fitting to be screwed onto the aluminum cap. A section of vinyl tubing was connected between the ½- stainless steel line and the end cap that enables easy removal of quartz filters and polyurethane foam (PUF) cartridges. A disassembled sample train with a calibrator end-cap assembly illustrates the adaptation (Figure 21).

Figure 20. Ducting samples to atmospheric semi-volatile samplers

.

Figure 21. Disassembled sample train illustrating bleed air SVOC sampling adapters

2.2.2.4 Adapting to diffusion type instruments

An injection molded tool chest was adapted for sampling bleed air from the sample manifold (Figure 22). Carbon loaded silicon tubing was used to route three 3/8” inside diameter hoses to the top and each end of the tool chest. Additional holes were drilled in the tool chest to enable routing of digital signal cables and power lines to the sensors. The three sample lines aided in rapidly purging the box to ensure a swift response. The ½ inch diameter holes in the box ensured that the box remained at atmospheric pressure.

The temperature within the box did rise due to the number of instruments running. This could have had potential for creating sensor drift but would not have prevented the research team from assessing whether the sensor did have some level of response to contaminants in the bleed air.

Figure 22. Chest for bleed sampling with diffusion sensors and low flow sensors instruments

2.3 Sensor/sensor technology plan

Table 3 lists instruments by type/detection method. More detailed instrument specifications, sensor images, and website links are located in Appendix I.

Table 3. Sensor technology evaluated

Sensor Technology	Sensor Name	Manufacturer	Make/Model	Analyte Detected
Ultra-Fine Particles				
Electrostatic Classifier		Thermo-Systems Company Incorporated (TSI)	3080	UFP
X-Ray Particle Neutralizer		TSI	3088	Particle Neutralizer
Condensation Particle Counter (CPC)	CPC	TSI	3775	UFP
CPC	Handheld CPC	TSI	3007	UFP
CPC	Nanoscan	TSI	3910	UFP

Sensor Technology	**Sensor Name**	**Manufacturer**	**Make/Model**	**Analyte Detected**
Corona Discharge	Partector II	Naneos	Partector II	UFP
Corona Discharge	IAQIndoor	Pegasor	IAQIndoor	UFP/PM
Corona Discharge	M3	Pegasor	M3	UFP
Ionization Chamber	Modified Smoke Detector	BRK Industries	First Alert/3120B	UFP/PM
Fine Particle (PM)				
Laser Time of Flight Spectrometer	Aerosol Particle Sizer (APS)	TSI	3321	UFP
Laser Light Scattering	Optical Particle Sizer (OPS)	TSI	3330	UFP
Laser Light Scattering	IPS 7100	Piera Systems	IPS 7100	PM
Laser/Light Scattering	Canaree	Piera Systems	I5	PM
Laser/Light Scattering	QTRAK XP	TSI	7545	PM
Laser/Light Scattering	ACES	Teledyne Controls		PM
Non-Dispersive Infra-Red Spectroscopy (NDIR)				
Gas Filter Correlation NDIR	Low Range CO	Teledyne	300e	CO
NDIR	Low Range CO_2	PP Systems	WMA-5	CO_2
NDIR	Low Range CO_2	TSI	7545	CO_2
NDIR	Low Range CO_2	Teledyne	ACES	CO_2
NDIR	Low Range CO_2	Pegasor	IAQIndoor	CO_2
Ion Mobility Spectrometer (IMS)				
IMS	Aerotracer	Air Sense		VOC

Sensor Technology	**Sensor Name**	**Manufacturer**	**Make/Model**	**Analyte Detected**
Cavity Ring Down Spectrometer (CRDS)				
CRDS	CRDS	Picaro	G2307	Formaldehyde, Methane
Gas Chromatography / Mass Spectroscopy (GC/MS)				
Portable GC/MS	Portable GC/MS	Teledyne FLIR	Griffin G510	VOC
Metal Oxide Sensor (MOS)				
MOS	Cabin Air Sensor	Astronics	Cabin Air Sensor	VOC
MOS	Canaree	Piera Systems	I5	VOC
MOS	Aerotracer	Airsense		VOC
Resonant Sensor Array				
Resonant Sensor Array	Cabin Air Quality Sensor	Pall	Cabin Air Quality Sensor	VOC
Photoionization Detector (PID)				
PID	QTRAK XP	TSI	7545	VOC
PID	MOKON II	Ametek	MOKON II	VOC
PID	Aerotracer	Airsense	Aerotracer	VOC
PID	ACES	Teledyne	ACES	VOC
PID	ppbRAE 3000	Honeywell	ppbRAE 3000	
Electrochemical (EC)				
EC	D8000	Interscan	D8000	Formaldehyde

Sensor Technology	**Sensor Name**	**Manufacturer**	**Make/Model**	**Analyte Detected**
EC	Formaldehyde Sensor Evaluation Module	Sensirion	SFA30	Formaldehyde
EC	Aerotracer	Airsense	Aerotracer	CO
EC	ACES	Teledyne	ACES	CO H2S, SO2, NO, NO2, O2, O3
EC	QTRAK XP	TSI	7545	Formaldehyde, CO, O3, NO, NO2

2.3.1 Ultrafine particle (UFP) sensing

Ultrafine particle (UFP) sensors were shown during the KSU Phase 1 research project as being one of the best markers for the presence of turbine oil and hydraulic fluids. Three different sensor technologies were evaluated during engine stand tests.

Condensation particle counting utilizes a fluid such as alcohol or water vapor to condense on the nanoparticles and grows their size sufficiently that they can be detected by an electrometer. Corona discharge sensors utilize a high voltage wire to attract nanoparticles. A change in the charge on the wire occurs when the nanoparticles land on the surface of the charged wire. An ionization sensor relies on a radioactive particle to impact nanoparticles, which imparts a charge on the particle. The particle is then attracted to a negatively or positively charged plate. The change in the charge on the plates is directly proportional to the number of particles that reach the charged plate.

The large number of nanoparticles may overwhelm some of the detectors. An electrostatic classifier may be used to study the number of particles across the size range of the instrument measuring capability. This may enable an instrument with lower dynamic detection capability to measure very high levels of particles. Some nanoparticle sensors tested had evidence of over-ranging with the quantity of particles produced during contaminant injection. Those cases will be further discussed in the results section.

The Pegasor PPS-M is unique in that its design permits it to sample ultrafine particles under high temperature and high-pressure conditions. It was originally developed for combustion studies in diesel engines. Two PPS-M sensors loaned by Pegasor provided KSU an opportunity to study

UFP concentration entering the heat exchange and concentrations exiting the heat exchanger. Jakubiak and Oberbek (2021) provide additional detailed information on application and testing of a smoke detector ionization module. They noted that Dahl et al. (2008) estimated the ionization sensors have a lower detection limit for 100 nm particles of 15,000 particles per cubic centimeter. Ultrafine particles are too small to be detected by columnated light sources (van de Hulst, 2021).

2.3.2 Particulate matter (PM) sensing

The smallest particles that may be sensed by a light source is approximately one-half the wavelength of the light source (van de Hulst, 2021). The time-of-flight spectrometer measures the velocity of particles ranging from 0.5 to 20 microns in aerodynamic diameter, over a range of 52 channels of size, and provides information on the range of particle size distribution and particle light scattering (TSI, 2013). The optical particle counter can measure particles ranging from 0.3 to 10 microns in aerodynamic diameter, over a range of 16 channels of size that are user selectable. This device uses an air sheath to direct the flow of sample particles through the optical path created by a laser beam. The laser light scattering methodology measures particle size ranging from 0.3 to 10 microns, over a range of 3 to 7 programmable bin sizes.

2.3.3 Non-dispersive infra-red (NDIR) sensing

The theory of operation of non-dispersive infra-red (NDIR) sensors is that the absorption of light energy at a selected wavelength for molecule species is compared to a reference gas without the molecule present. The gas filter correlation method passes a filter wheel across the optical path to obtain a signal without the analyte. Some types of NDIR instruments use dual cells, one with the sample gas, and the second cell filled with clean dry air. Low range measurements are achieved by increasing the length of the light path between the light source and the detector. Molecules such as carbon dioxide and carbon monoxide utilize NDIR methodology for low range measurements.

2.3.4 Ion mobility spectrometry (IMS)

The ion mobility spectrometer (IMS) utilizes a radioactive source to ionize the sample gas, and a high voltage within a chamber near atmospheric pressure to cause ions to move through a series of electric shutters to create pulses of ions that migrate toward a plate detector. The speed at which the ions reach the detector is based on the electrical mobility of the ionized particles. Analytes that do not form ions cannot be analyzed by IMS. Different types of ions with similar electrical characteristics may reduce the ability of the IMS to resolve the different VOC species.

2.3.5 Cavity ring-down spectrometry (CRDS)

The cavity ring-down spectrometry (CRDS) sends a pulsed burst of light energy into a mirrored chamber and measures the time for the light to die out. The light beam is tuned to the analyte of interest. An analyte will reduce the amount of time for the burst of light to die out. The higher the concentration of the analyte, the shorter the time. This method has applicability from trace concentrations in the part per trillion level up to part per million concentrations. The pressure and temperature of the measurement chamber must be carefully controlled to achieve part per trillion concentration sensitivity.

2.3.6 Portable gas chromatography/mass spectrometry (GC/MS)

The low vacuum gas chromatography/mass spectrometry (GC/MS) uses molecular weight and molecular size to separate analytes. The samples are typically concentrated on an adsorbent media or a trap and then are quickly released into a capillary column to further separate the molecules based on size and molecular polarity. The low vacuum GC/MS must use a custom library tailored to the application, rather than using the NIST library of full size, high vacuum GC/MS. The low vacuum GC/MS is intended for rapid qualitative field identification. Its mass analyzer is shielded with an inert buffer gas, rather than being maintained at a high vacuum. The portable low vacuum GC/MS is complimentary to the full-scale high vacuum GC/MS and does not replace the capabilities offered by full scale laboratory grade instruments.

2.3.7 Metal oxide sensors (MOS)

Metal oxide sensors are a large class of semiconductor sensors. The general mechanism utilized by the various classes of metal oxide sensors is to expose the sensor to contamination. The resistance of the surface of the sensor decreases in resistance as increasing levels of contamination are applied. Mixtures of contaminants do not necessarily increase the response if the material. The chemical molecular characteristics, the material of the sensor, and the physical composition of the sensor also influence the sensor response. The metal oxide sensor types of the sensors utilized in this test were not provided to KSU, nor were the operating characteristics, so only the basic sensor response to contaminants can be evaluated.

2.3.8 Resonance sensor array

A resonance sensor array provides information about changes in sensor resonant frequencies to evaluate air contamination. The sensor data is analyzed by a processor that evaluates response from the sensors within the array and compares the response to a database created for use of the sensor for specific contaminant models.

2.3.9 Photoionization sensor

A photoionization sensor uses a high energy ultraviolet light source to excite the molecules of volatile compounds within the air. There are three energy levels to choose from, 9.8, 10.6, and 11.7 electron volts (eV). Almost 1000 compounds which can release light energy have been identified in bleed air. Approximately 50-60 compounds reported in bleed air studies (Mayer, 2022) can release a photon of light. The response of a photoionization will vary from compound to compound. The total effect of a compound mixture excitation by the light source is a sum of the effects of each of the compounds and their concentration and reactivity to the light source (TSI, 2022; Alphasense LTD, 2017).

2.3.10 Electrochemical sensors

Electrochemical gas sensors have an electrolyte reservoir which contains a sensing electrode (Ametek Alphasense, 2022). Working electrodes in the sensor are separated from the sensing electrode by a membrane that has chemical selectivity. A counter electrode balances the reaction of the working electrode. A reference electrode helps to maintain sensor measurement stability.

2.4 Laboratory chemical sampling plan

The laboratory chemical sampling plan includes captured samples for analysis by United States Environmental Protection Agency (EPA) test methods at external laboratories. The methods selected for analysis include EPA TO-11A for aldehydes, EPA TO-13A for semi-volatile sampling, quartz filter sampling for organophosphorus compounds, EPA TO-15 Summa Canisters for short carbon chain VOC, and EPA TO-17 for longer chain VOC compounds. A summary of the methods and quantities of samples is provided in Table 4.

Separate laboratory chemical sampling for independent verification of sampling methods and analysis was performed by a chemical engineer from the U.S. Naval Air Warfare Center Aircraft Division (NAWCAD). NAWCAD's laboratory chemical sampling plan, sampling methods, and chemical analysis results have been reported by Ortiz-Martinez (2023).

Table 4. Summary of laboratory sample methods

Analyte	Method	Media	Flow Rate (SLPM)	Sample Duration (Minutes)	Sample Size (Liters)	No. of Samples
Carbonyls	EPA TO-11A	DNPH Cartridges	1.5	20	30	42

Analyte	Method	Media	Flow Rate (SLPM)	Sample Duration (Minutes)	Sample Size (Liters)	No. of Samples
TCP Isomers	EPA 8270 and EPA TO-13A	102 mm Whatman #4 Quartz Filters	300	10	3000	46
Polyaromatic Hydrocarbons	EPA TO-13A	High Volume PUF Cartridges	300	10	3000	21
VOC	EPA TO-15	Tedlar® Bag	1	2	3	35
VOC	EPA TO-15	Summa Canister ®	0.2	30	6	36
VOC	EPA TO-17	Tenax ® Thermal Desorption Cartridge	0.2	20	4	45

2.4.1 Dinitrophenyl hydrazine (DNPH) cartridge samples for EPA TO-11A analysis

AAC Laboratories provided WAT037500 Sep-Pak DNPH-silica cartridges for performing dinitrophenyl hydrazine (DNPH)[1] carbonyl derivatization (Figure 23). Ozone scrubbers Waters SEP-Pak Ozone Scrubber Potassium Iodide, Plus short cartridge, (part number WAT054420) were not present in the sample media received but would normally be utilized in series with the Waters WAT037500 DNPH-Silica-Plus short cartridges. Ho et al. (2013) reported that measured carbonyl concentrations were 4.9 to 13.5% lower in samples collected without any ozone traps, compared to those with a commercially available ozone scrubber or potassium iodide (KI) denuder. They also cautioned that iodine (I2) and hydroxyl ion (OH-) can inhibit the kinetics of carbonyl derivatization. AAC laboratories procedure did not use an ozone scrubber to remove ozone ahead of DNPH carbonyl derivatization.

A vane pump (Figure 24) was utilized to draw vacuum on the mass flow controllers. A quantity of 42 DNPH sample cartridges (Waters Sep-Pack Part number WAT037500) without ozone scrubbers were sent to Atmospheric Analysis & Consulting, Inc., Oxnard, CA, for carbonyl analysis by EPA TO-11A.

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[1] Dinitrophenyl hydrazine or DNPH is a reagent used in organic analysis and detection of ketones and aldehydes.

A vacuum pump (Figure 24) connected to Alicat mass Flow controllers[2] (Figure 25) was used to draw approximately 30-liters of air at a 1.5 standard liters per minute (SLPM) (±0.5%)[3] mass flow for 30 minutes through DNPH sample concentration cartridges.

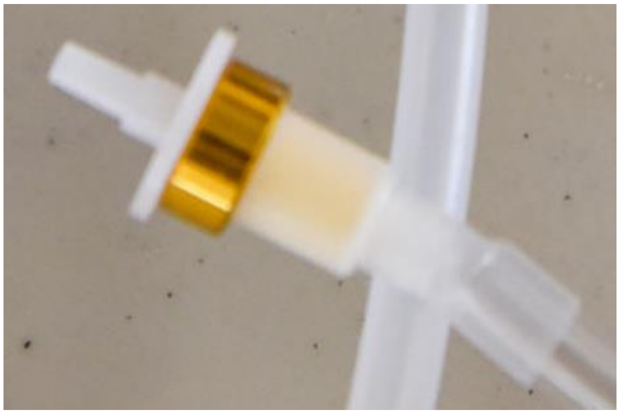

Figure 23. Waters Sep-Pak DNPH-Silica Cartridge

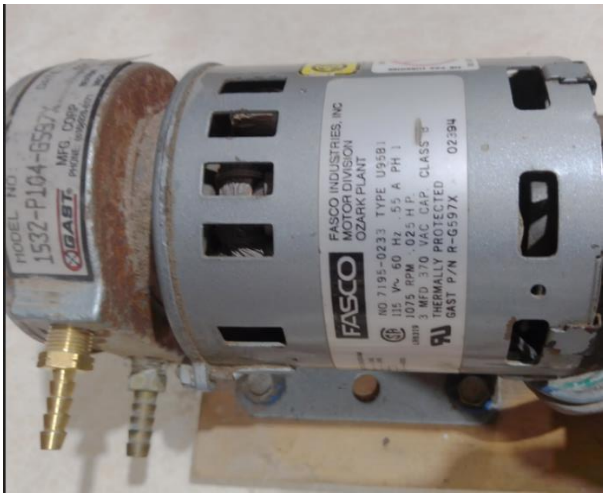

Figure 24. Fasco Vane Pump, Model No. 1532-P104-G597X

A calibrated Thermo-Systems Engineering Company Incorporated (TSI) digital mass flow meter[4] (Figure 26) was utilized as a transfer standard to set the mass flow setpoints of the Alicat mass flow controllers (Table 5, Figure 25) on a daily basis prior to test for the EPA TO-11A DNPH Cartridges. The calculated flows were based on the calibrated readings obtained from the calibrated flowmeter. The full TO-11A sample table including field notes is found in Table 5.

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[2] Established gas flow accuracy at 1 SLPM of ±0.5% of reading.

[3] Standard liter per minute (SLM or SLPM) is a unit of volumetric flow rate of a gas at standard conditions for temperature and pressure (STP). These conditions are 0 ˚Celsius and 1 atmosphere (atm) of pressure (100 kilopascals (kPa)).

[4] Established gas flow accuracy at 1 SLPM of ±2.0% of reading.

Figure 25. Alicat mass flow controllers with DNPH and Tenax thermal desorption tubes

Figure 26. TSI Model 4000 flowmeter transfer standard for mass flow controllers
(Photo courtesy of TSI Incorporated)

Table 5. EPA TO-11A sampling information

Test Condition	Time (start)	Engine Bleed Temp [°C]	Sample No	SLPM	SLPM	Volume [Std L]	Sample No	Volume [Std L]	Volume [Std L]	Volume [Std L]
Manufacturer	Waters			Alicat	TSI			Alicat	TSI	
Model	Sep-Pak DNPH-silica cartridges			Mass Flow Controller	Mass Flow Meter			Mass Flow Controller	Mass Flow Meter	
Part Number	WAT037500			MC-2SLPM-D-24V	4043H			MC-2SLPM-D-24V	4043H	
Accuracy (% of Reading)				±0.5%	±2%			±0.5%	±2%	
Serial Number				16789	31231007			17129	31231007	
Monday 05/16/2022			Inlet				Bleed			
Field blank	17:15	N/A	8							
Shipping blank			1							
Baseline	14:50	200	2	1.54	1.61	32.2	3	1.56	1.56	31.2
Eastman 2389 3cst	16:50	200	4	1.54	1.60	32.0	5	1.56	1.56	31.2
Eastman 2389 3cst	18:50	260	6	1.66	1.73	34.6	7	1.63	1.69	33.8
Tuesday 05/17/2022										
Baseline	8:50	200	9	1.51	1.52	30.4	10	1.63	1.62	32.4
Mobil Jet II	10:20	200	11	1.60	1.63	32.6	12	1.61	1.61	32.2
Mobil Jet II	11:57	250	13	1.54	1.58	31.6	14	1.60	1.59	31.8
Baseline	15:18	200	15	1.58	1.66	33.2	16	1.60	1.61	32.2
Mobil 387	16:50	200	17	1.42	1.48	29.6	18	1.50	1.53	30.6
Mobil 387	18:20	250	19	1.46	1.51	30.2	20	1.50	1.53	30.6
Field Blank	17:20	N/A	21							
Wednesday 05/18/2022										
Baseline	8:30	200	22	1.50	1.50	30.0	23	1.50	1.48	29.6
PE-5	9:55	200	24	1.50	1.51	30.2	25	1.52	1.50	30.0
PE-5	11:47	250	26	1.52	1.52	30.4	27	1.55	1.52	30.4
Baseline	14:32	200	28	1.52	1.55	31.0	29	1.55	1.54	30.8

Test Condition	Time (start)	Engine Bleed Temp [°C]	Sample No	SLPM	SLPM	Volume [Std L]	Sample No	Volume [Std L]	Volume [Std L]	Volume [Std L]
Manufacturer	Waters			Alicat	TSI			Alicat	TSI	
Model	Sep-Pak DNPH-silica cartridges			Mass Flow Controller	Mass Flow Meter			Mass Flow Controller	Mass Flow Meter	
Part Number	WAT037500			MC-2SLPM-D-24V	4043H			MC-2SLPM-D-24V	4043H	
Accuracy (% of Reading)				±0.5%	±2%			±0.5%	±2%	
Serial Number				16789	31231007			17129	31231007	
HyJet IV-A	16:27	200	30	1.52	1.52	30.4	31	1.54	1.51	30.2
HyJet IV-A	17:55	250	32	1.52	1.52	30.4	33	1.55	1.52	30.4
Field Blank	17:00	N/A	34							
Shipping Blank	16:30	N/A	N/A							
Thursday 05/19/2022										
Baseline	8:05		35	1.44	1.47	29.4	36	1.49	1.48	29.6
Deicing Type1	8:05	200	37	1.48	1.50	30.0	38	1.50	1.49	29.8
Field Blank	11:22		39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Baseline	12:19		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mobil Jet II	14:00	200	N/A	N/A	N/A	N/A	40	1.50	1.52	30.4
Mobil Jet II	15:46	250	41	1.48	1.52	30.4	42	1.49	1.51	30.2

The list of DNPH sample identifications and sample numbers is found in Appendix E. The DNPH cartridges were sealed in individual bags pictured in Figure 27. The DNPH Cartridges were stored in a freezer until shipment. During shipment, they were kept cold in an ice chest with a substantial amount of blue ice (Figure 28). Chains of Custody for the EPA TO-11A samples are found on pages 12 through 15 of Atmospheric Analysis & Consulting, Inc. Report Number 221141, dated June 6, 2022 found in the accompanying dataset (KSU, 2024).

Figure 27. Waters PN WAT037500 DNPH cartridges without ozone scrubbers

Figure 28. Ice chest and blue ice to maintain sample media at low temperature in transit

2.4.1 Tricresyl phosphate, triphenyl phosphate, and tributyl phosphate Isomers EPA Method 8270E (modified)

The High-Volume Sampling Module was developed to run at a rate of 4 to 10 SCFM (0.114 to 0.285 std m /min) to obtain a sample volume greater than 300 m^3 (EPA, 1999). The EPA TO-13A procedure notes that sample volumes less than 300 m^3 still collect enough polyaromatic hydrocarbons (PAH) on the filter/polyurethane foam (PUF) for quantitation. The sample quantity to be obtained is reliant upon the user’s data quality objectives. A sample of 3000 liters at 300 liters/minute was acquired during the 10-minute sample period with Tisch Environmental High-Volume Samplers, SN 2572, and SN2578.

A quantity of 46 samples (Figure 29) were collected on 101.6 mm (4 in. Diameter) Tisch Environmental TE-R (Whatman QMA) quartz filters for PUF Samplers, to be analyzed for organophosphates. The quartz filter samples were sent to RJ Lee Group, Columbia Basin Analytical Laboratories, Pasco, WA, for speciated phosphate isomer analysis by EPA TO-13/EPA Method 8270e (modified). The list of organophosphates requested came from Table 15 of the European Aviation Safety Agency (EASA) Interim Cabin Air Study (Schuchardt, 2014). See Appendix G for the list of these target organophosphates. The chain of custody forms are on page 236 through 242 of RJ Lee report number 205178, Revision 1, dated November 16, 2023 (KSU, 2024).

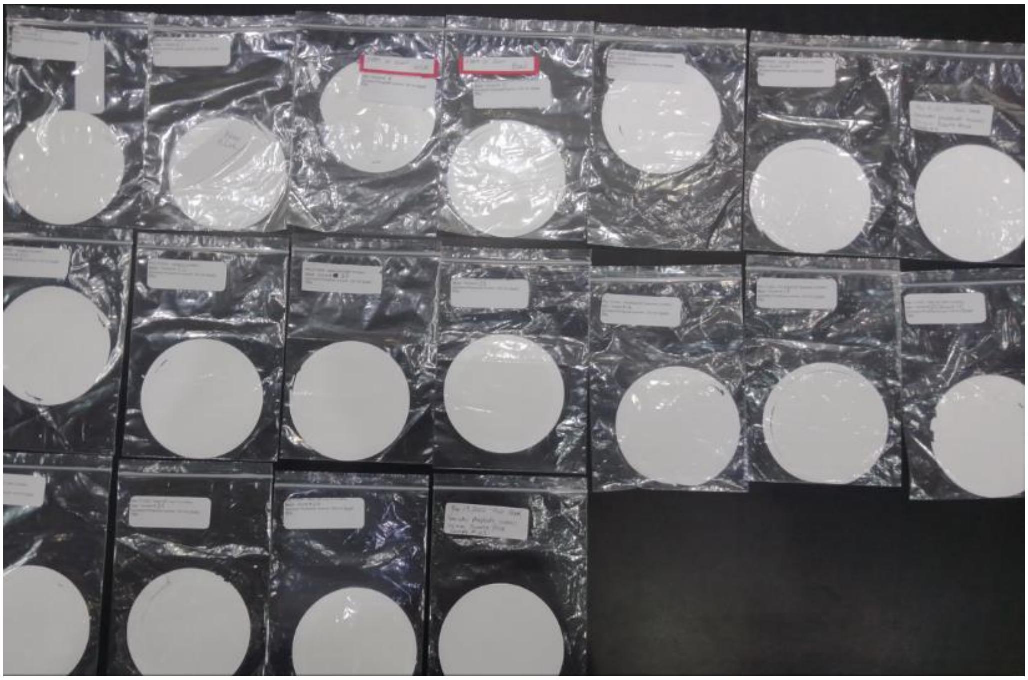


Figure 29. Quartz filters prepared for shipment

2.4.2 Polyaromatic hydrocarbons by EPA TO-13A

Polyaromatic hydrocarbons were collected on polyurethane foam PUF/XAD Resin[5] cartridges (Figure 21) using a high-volume air sampler from Tisch Environmental (Figure 20). A sample of 3000 liters was acquired during the 10- minute sample period.

---

[5] XAD-2 (PUF/XAD) cartridges packed in glass sleeves are used for collecting semi volatile organic compounds (SVOC) for example, polyaromatic hydrocarbons (PAH's), phthalates, and certain organic compounds using a high-volume sampler (250 L/min) to meet EPA and ASTM method specification for ambient air sampling.

The chain of custody for PUF-XAD samples 2-14 is on page 48 of RJ Lee report number 205131, Revision 1, dated November 23, 2023 (KSU, 2024). The chain of custody for PUF-XAD samples 15-19 and 23-24 is on page 66 of RJ Lee report number 205177, Revision 1, dated November 16, 2023 (KSU, 2024). The quantity of organophosphates, including tricresyl phosphate (TCP), triphenyl phosphate (TPP), and tributyl phosphate (TBP) isomers collected over the 10-minute sample period was of adequate size that some sample had to be diluted for analysis. Those samples are noted with a "d" in the remark's column of the analytical report by R.J. Lee Laboratory. Due to a supply chain issue, there were insufficient PUF/XAD cartridges to gather samples in parallel with each quartz filter sample. Glass sample cartridges were sealed in aluminum foil (Figure 30) and placed in a freezer prior to shipment. The samples were shipped in a cooler with blue ice, similar to that shown in Figure 28 to RJ Lee Laboratories along with the quartz filter samples. The samples were analyzed according to EPA method TO 13A. A copy of the chain of custody forms for the EPA TO-13A samples is in Appendix F.

Figure 30. PUF-XAD cartridges wrapped for shipment

2.4.3 Tedlar bag samples for toxic organic (TO-15) qualitative analysis

Thirty-five Tedlar® bags were collected and shipped to Teledyne Griffin in West Lafayette, IN. A typical 3-liter Tedlar ® bag is shown in Figure 31. The bags were filled with a dual headed vacuum pump to fill bags from engine inlet and engine bleed sample air simultaneously (Figure 32).

Figure 31. Typical 3-liter sampling bag

Figure 32. Dia-Vac dual head pump, Model M102-BT-AA1 s/n 1406492

Of the 35 bags, one bag was broken, and three were empty or nearly empty. A two-headed diaphragm vacuum pump was utilized to simultaneously capture samples from engine inlet and engine bleed sample streams.

2.4.4 EPA TO-15 target compounds plus tentatively identified compounds (TICS)

A quantity of 36 Summa Canisters with 30-minute flow restrictors (Figure 33) were utilized to acquire EPA TO-15 samples over the same 30-minute interval that EPA TO-11A and EPA TO-15 samples were acquired.

Figure 33. Copper line & 30-minute summa canister flow controller on summa canister

The summa canisters were sent to Atmospheric Analysis & Consulting, Inc., Oxnard, CA, for EPA TO-15 Analysis, including tentatively identified compounds. The Chains of Custody forms for the summa canisters are appended to three analysis reports. The chain of custody form for samples 1 through 12 is found on page 24 of report number 221095, dated May 26, 2022 (KSU, 2024). The chain of custody form for samples 13-24 is found on page 24 of report number 221106 (KSU, 2024). The chain of custody form for samples 25-36 is found on page 24 of report number 221134 (KSU, 2024)

2.4.5 EPA TO-17 target compounds

Forty-five single-bed Tenax TA cartridges (Figure 34), 15 from Markes and 30 from TDU, were collected at a mass flow rate of 0.2 Standard Liters Per Minute (SLPM) (+/- 0.5%) for 30 minutes using Alicat® Digital Mass Flow controllers (Figure 25) whose flow was verified against a transfer standard (Table 6).

Figure 34. Single bed Tenax cartridges

The Tenax cartridges were foil wrapped and shipped in an ice chest to preserve the samples (Figure 35). These samples were sent to RJ Lee Group, Columbia Basin Analytical Laboratories, Pasco, WA, for EPA TO-17 analysis. The chain of custody forms for the TO-17 sample media are found on pages 217 through 220 of RJ Lee report number 205179, dated September 28, 2022 (KSU, 2024). Figure 36 is an example of one of the TO-17 chain of custody pages.

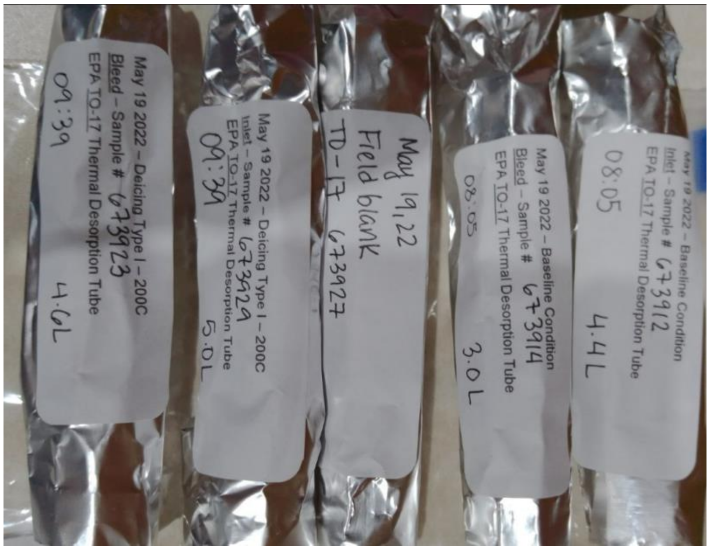
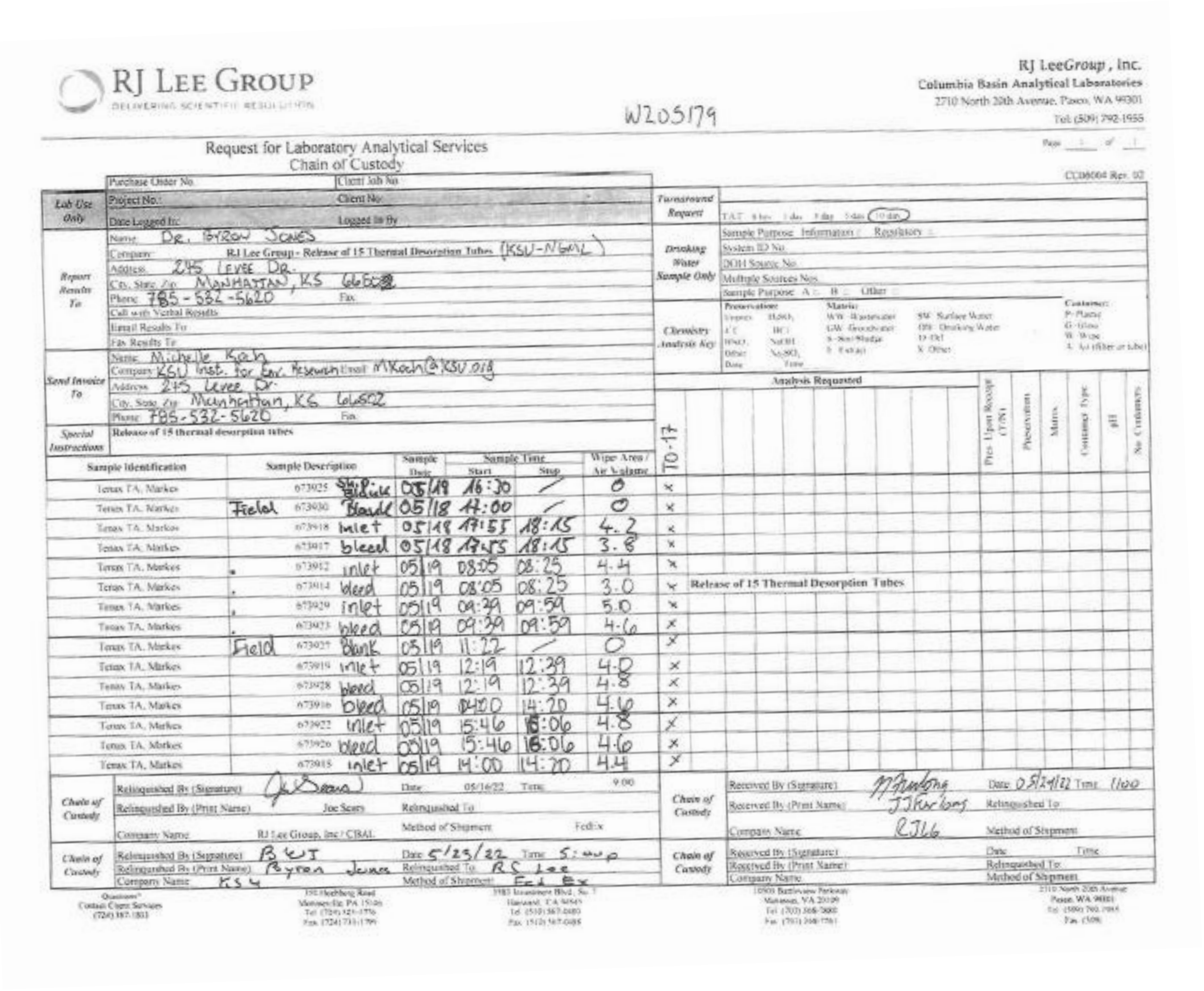


Figure 35. Tenax thermal desorption tubes sealed and labeled for shipment

Transfer of sample identification from the TO-17 Chain of Custody form was not sufficient in the final report to align samples with the test conditions in Table 6. The KSU identity is paired with the RJ LEE laboratory ID in Appendix E, Laboratory Chemical Sample Log.



RJ LEE GROUP
DELIVERING SCIENTIFIC RESOLUTION

W205179

RJ LeeGroup, Inc.
Columbia Basin Analytical Laboratories
2710 North 20th Avenue, Pasco, WA 99301
Tel: (509) 792-1955

Request for Laboratory Analytical Services
Chain of Custody

Page 1 of 1

CC00004 Rev. 02

	Purchase Order No.	Client Job No.
Lab Use Only	Project No.:	Client No.
	Date Logged In:	Logged In By
Report Results To	Name: DR. BYRON JONES	
	Company: RJ Lee Group - Release of 15 Thermal Desorption Tubes (KSU-NGML)	
	Address: 245 LEVEE DR.	
	City, State, Zip: MANHATTAN, KS 66502	
	Phone: 785-532-5620	Fax:
	Call with Verbal Results	
	Email Results To	
	Fax Results To	
Send Invoice To	Name: Michelle Koch	
	Company: KSU Inst. for Env. Research	Email: MKoch@KSU.org
	Address: 245 Levee Dr.	
	City, State, Zip: Manhattan, KS 66502	
	Phone: 785-532-5620	Fax:
Special Instructions	Release of 15 thermal desorption tubes	

Turnaround Request: T.A.T. 8 hrs. 1 day 3 day 5 day [✓ 10 day]

Drinking Water Sample Only:
Sample Purpose: Information ☐ Regulatory ☐
System ID No.
DOH Source No.
Multiple Sources Nos.
Sample Purpose: A ☐ B ☐ Other ☐

Chemistry Analysis Key:
Preservation: Preservation Matrix: WW- Wastewater, GW- Groundwater, S- Soil/Sludge, SW- Surface Water, DW- Drinking Water, O- Oil, X- Other; Container: P- Plastic, G- Glass, W- Wipe

Sample Identification	Sample Description		Sample Date	Sample Time Start	Sample Time Stop	Wipe Area / Air Volume	TO-17
Tenax TA, Markes	673925	Blank	05/18	16:30	/	0	x
Tenax TA, Markes	Field 673930	Blank	05/18	17:00	/	0	x
Tenax TA, Markes	673918	inlet	05/18	17:55	18:15	4.2	x
Tenax TA, Markes	673917	bleed	05/18	17:55	18:15	3.8	x
Tenax TA, Markes	673912	inlet	05/19	08:05	08:25	4.4	x
Tenax TA, Markes	673914	bleed	05/19	08:05	08:25	3.0	x
Tenax TA, Markes	673929	inlet	05/19	09:39	09:59	5.0	x
Tenax TA, Markes	673923	bleed	05/19	09:39	09:59	4.6	x
Tenax TA, Markes	Field 673927	Blank	05/19	11:22	/	0	x
Tenax TA, Markes	673919	inlet	05/19	12:19	12:39	4.0	x
Tenax TA, Markes	673928	bleed	05/19	12:19	12:39	4.8	x
Tenax TA, Markes	673916	bleed	05/19	14:00	14:20	4.6	x
Tenax TA, Markes	673922	inlet	05/19	15:46	16:06	4.8	x
Tenax TA, Markes	673926	bleed	05/19	15:46	16:06	4.6	x
Tenax TA, Markes	673915	inlet	05/19	14:00	14:20	4.4	x

Analysis Requested: TO-17 — Release of 15 Thermal Desorption Tubes

Pres. Upon Receipt (Y/N) | Preservation | Matrix | Container Type | pH | No. Containers

Chain of Custody
Relinquished By (Signature): Date: 05/16/22 Time: 9:00
Relinquished By (Print Name): Joe Sears Relinquished To:
Company Name: RJ Lee Group, Inc / CBAL Method of Shipment: FedEx

Chain of Custody
Relinquished By (Signature): BWJ Date: 5/23/22 Time: 5:40p
Relinquished By (Print Name): Byron Jones Relinquished To: RJ Lee
Company Name: KSU Method of Shipment: Fed Ex

Chain of Custody
Received By (Signature): Date: 05/24/22 Time: 1100
Received By (Print Name): JJ Kurlong Relinquished To:
Company Name: RJLG Method of Shipment:

Chain of Custody
Received By (Signature): Date: Time:
Received By (Print Name): Relinquished To:
Company Name: Method of Shipment:

Figure 36. Representative EPA TO-17 chain of custody form

Table 6. Sampling information for EPA TO-17 cartridges

Manufacturer	Markes®/ Supelco®			Alicat®	TSI®	Volume [Std L]	Sample No	Alicat®	TSI®	Volume [Std L]
Model	Single Bed Thermal Desorption Tube			Mass Flow Controller	Mass Flow Meter			Mass Flow Controller	Mass Flow Meter	
Part Number				MC-2SLPM-D-24V	4043H			MC-2SLPM-D-24V	4043H	
Accuracy (% of Reading)				±0.5%	±2%			±0.5%	±2%	
Serial Number				16790	31231007			17668	31231007	
Test Condition	Time (start)	Engine Bleed Temp [°C]	Sample No							
Monday 05/16/2022			Inlet				Bleed			
Field blank	17:15	N/A	463638							
Shipping blank			463641							
Baseline	14:50	200	A035217	0.23	0.21	4.2	A035205	0.38	0.16	3.2
Eastman 2389 3cst	16:50	200	463636	0.23	0.22	4.4	463637	0.42	0.20	4.0
Eastman 2389 3cst	18:50	260	A035254	0.23	0.22	4.4	463647	0.42	0.21	4.2
Test Condition	Time (start)	Engine Bleed Temp [°C]	Sample No							
Tuesday 05/17/2022			Inlet				Bleed			
Baseline	8:50	200	463634	0.24	0.20	4.0	463631	0.41	0.18	3.6
Mobil Jet II	10:20	200	N/A	N/A	N/A	N/A	463643	0.44	0.20	4.0
Mobil Jet II	11:57	250	463624	0.24	0.23	4.6	463623	0.44	0.22	4.4
Baseline	15:18	200	463648	0.22	0.24	4.8	463639	0.40	0.22	4.4
Mobil 387	16:50	200	463626	0.18	0.20	4.0	463633	0.38	0.20	4.0
Mobil 387	18:20	250	463625	0.18	0.21	4.2	463646	0.38	0.20	4.0

Manufacturer	Markes®/ Supelco®			Alicat®	TSI®	Volume [Std L]	Sample No	Alicat®	TSI®	Volume [Std L]
Model	Single Bed Thermal Desorption Tube			Mass Flow Controller	Mass Flow Meter			Mass Flow Controller	Mass Flow Meter	
Part Number				MC-2SLPM-D-24V	4043H			MC-2SLPM-D-24V	4043H	
Accuracy (% of Reading)				±0.5%	±2%			±0.5%	±2%	
Serial Number				16790	31231007			17668	31231007	
Field Blank	17:20	N/A	463622							
Test Condition	Time (start)	Engine Bleed Temp [°C]	Sample No							
Wednesday 05/18/2022			Inlet				Bleed			
Baseline	8:30	200	463642	0.18	0.13	2.6	463635	0.38	0.15	3.0
PE-5	9:55	200	A035183	0.25	0.22	4.4	463644	0.43	0.20	4.0
PE-5	11:47	250	463650	0.26	0.21	4.2	A034773	0.40	0.16	3.2
Baseline	14:32	200	A035167	0.22	0.19	3.8	A035270	0.40	0.18	3.6
Hyjet IV-A	16:27	200	Y59084	0.24	0.21	4.2	Y59070	0.44	0.20	4.0
Hyjet IV-A	17:55	250	673918	0.25	0.21	4.2	673917	0.44	0.19	3.8
Field Blank	17:00	N/A	673930							
Shipping Blank	16:30	N/A	673925							
Test Condition	Time (start)	Engine Bleed Temp [°C]	Sample No							
Thursday 05/19/2022			Inlet				Bleed			
Baseline	8:05		673912	0.25	0.22	4.4	673914	0.36	0.15	3.0
Deicing Type1	8:05	200	673929	0.25	0.23	4.6	673923	0.40	0.25	5.0
Field Blank	11:22		673927	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Baseline	12:19		673919	0.20	0.20	4.0	673928	0.40	0.24	4.8
Mobil Jet II	14:00	200	673915	0.20	0.22	4.4	673916	0.40	0.23	4.6
Mobil Jet II	15:46	250	673922	0.20	0.24	4.8	673926	0.39	0.23	4.6

2.5 Test variables (injected fluid contaminants)

There are multiple considerations that must be evaluated to decide which oils, hydraulic fluids, and deicing fluids should be evaluated to rank sensors and instrument packages on ability to provide reliable and correct warnings of bleed air contamination while minimizing false warnings from other sources that may be encountered during normal ground and flight operations.

2.5.1 Synthetic oils

Synthetic oils may be segregated by their approximate viscosity. Viscosity is a measure of fluidity of the oil called centistokes (cSt). The oils are segregated by their viscosity at 100 ˚F, as 3, 4, or 5 cSt oils. The thinner oils are typically used for APUs which may have to be started at altitude while sitting in the very cold environment of the unpressurized aircraft. The higher viscosity oils are utilized where there are elevated temperatures and operating loads in the propulsion engines. Generally, the base stock of the oils is similar between brands, with major brand differences being in the additive packages that protect against oil oxidation, wear, and thermal degradation. Four (4) cSt oils are typically used in military applications. Five (5) cSt oils have been segregated into three groups based on application for the oil types. The “Standard” category of Mil-PREN-23699 (DOD, 2014) encompasses most in-service turbine oils. The high thermal stability (HTS) class is growing in popularity and several operators are transitioning from standard to HTS class oils for their aircraft fleets.

A recent survey of operators indicates that the most commonly used oils accounting for greater than 99% of the oils used for commercial aviation include Mobil Jet Oil II, Eastman Turbo Oil 2197, Eastman Turbo Oil 2380 and Eastman Turbo Oil 2389, Nyco TN600, Mobil Jet Oil 387, Aeroshell 560, and Aeroshell 500. Their preferences for oil and hydraulic fluid are also summarized in Table 7.

The fluid selection process for this study considered the variation in chemistry of fluid types. Three types of turbine oil were identified based on specification types. Mil-PRF-7808 (DOD, 1997), Grade 3 Specification (3 cSt) oils have lower viscosity than 5 cSt oils and are utilized primarily in colder operating environments. The 5 centistoke oils are used for warmer environments, and two classes of lubricants have been segregated further into standard type oils, and HTS oils. Five cSt oils, standard class oils are used in most commercial aircraft, but the use of HTS class oils is increasing. The oils selected to represent these types and classes were Eastman 2389 as the representative 3 cSt oil, Mobil Jet II as the representative 5 centistoke standard class oil, and Mobil 387 as the representative 5 cSt HTS class oil. Specifications for the selected turbine oils are found in Appendix A.

2.5.2 Synthetic hydraulic fluids

Hydraulic fluids are classified by Mil-PRF-5606 (DOD, 2018) based in part on the hydraulic system pressure that they are designed to perform in. Commercial aircraft are equipped with either a 3000 pounds per square inch (psi) hydraulic system or a 5000psi hydraulic system on some newer aircraft models. The fluid characteristics for these two hydraulic system types vary, so it is reasonable to conclude there may be different sensor responses to the two types of hydraulic fluids, and that one fluid from each type should be evaluated.

Hydraulic fluid manufacturers and airlines have provided preference information to the KSU Phase II project to aid in selection of fluids. Greater than 99% of the hydraulic fluid brands include Skydrol PE-5, ExxonMobil HyJet V, Eastman Skydrol LD-4, HyJet IV-A plus, Skydrol 500B, Red Oil, and Skydrol V. Hydraulic fluids tested during the engine test at KSU included Skydrol PE-5 (5000 psi fluid), and ExxonMobil HyJet IV-A+ (3000 psi fluid). Characteristics of the selected hydraulic fluids are found in Appendix A.

2.5.3 Deicing/anti-icing fluids

Aircraft deicing fluids are formulated for their flow-off capability based on the application requirements for their use. These requirements are provided in Aerospace Standard (AS) AS5900B (SAE International, 2021).The four types of deicing fluids are presented in (Struk, 2016). Propylene glycol is the most common primary ingredient in undiluted deicing fluids. Surfactants are added to the fluid to reduce surface tension of the sprayed product. Type 1 fluid is applied hot and is primarily intended for ice removal from exterior surfaces. The most likely path for deicing fluid to enter the environmental control system (ECS) is during ground operations if inadvertently sprayed into an engine or APU inlet. The representative deicing fluid selected was Safewing MP / LFD 88 Dilute Type 1 Aircraft Deicing Fluid. Specifications for the selected test fluid are found in Appendix A. Table 8 summarizes the properties of Type 1-IV deicing fluids.

Table 7. Informal airline survey of oil & hydraulic fluid use

	Air Canada	**Alaska Airlines**	**American Airlines**	**Delta Airlines**	**Frontier Airlines**	**Spirit Airlines**	**United Airlines**
APU Oil	Mobil 256 (787 only) Mobil Jet II (All other fleets)	Mobile Jet II (737) Eastman 2389 (Airbus)	Eastman 2389	Eastman 2380 Alternates: Mobil Jet II, Mobil Jet 254	Eastman 2380 Alternate: Mobil Jet II	Nyco 600	Eastman 2389
Engine Oil	Mobil Jet II	Mobil Jet II	Eastman 2197	Eastman 2197 (717, 757, 767, 777, A330, 747, A350, A220) Mobil Jet II (737, A319/320/321) Alternates: Eastman 2380, Mobil Jet 254, Mobil Jet 387	Eastman 2380 Alternate: Mobil Jet II	Nyco 600	Mobil Jet II (737 only) Eastman 2197 (all other fleets)
Hydraulic Fluid	HyJet V	Mobil Hy Jet IV A-plus	Mobil Hy Jet V (B787 only) Eastman Skydrol PE-5 (all other fleets)	Skydrol PE-5	Skydrol PE-5 Alternates: LD4, HyJet IV-A Plus, HyJet V, Skydrol 500B4	HyJet V	Mobil Hy Jet V (B787 only) Eastman Skydrol PE-5 (all other fleets)
Recently Changed?	Recently standardized hydraulic fluid to HyJet V-previously used LD4.	No	No	No	No	Recently Changed to Nyco 600 for commercial reasons ($$$)	No
Considering a Change?	Doing a type of trial on CFM56-5B engines with MJO387	No	We understand that Eastman may be developing a TCP-free oil. This will be evaluated once available.	Supply chain considering hydraulic fluid change to HyJet V.	No	No	No

Table 8. Types of aircraft deicing fluid

Type	**Color**	**Fluid/water**	**Application**	**Min Rotation Speed**
I	red-orange	55:45	hot – ice removal	none
II	clear-straw	75:25	de-ice/anti-ice	100 knots
III	yellow-green	approx. 65:35	de-ice/anti-ice	60 knots
IV	emerald green	undiluted	ice prevention	100 knots

Three turbine oils, two hydraulic fluids, and one deicing fluid were selected for testing. One oil from Mil-PRF-7808 was selected because this class is designed for cold weather operation and has lower viscosity. Eastman 2389 was selected because it is used by one of the largest airlines in the USA for its APU fleet. Mobil Jet Oil II was selected as the representative Mil-PRF-23699 standard turbine oil because it is predominantly used by aircraft operators. Mobil 387 was selected as a representative MIL-PRF-23699 high thermal stability oil.

High thermal stability oils are gaining in popularity by operators and are being substituted for standard grade turbine oils. Eastman Skydrol PE-5 was selected for test because it is representative of the 5000 psi hydraulic fluids in service. HyJet IV-A plus was selected as a representative hydraulic fluid for test because it is one of the most widely used 3000 psi hydraulic fluids. The 5000 psi hydraulic fluids are being substituted for 3000 psi fluids by some operators. Safewing MP Type 1 diluted deicing fluid was selected for testing because of its ready availability. No dilution was necessary, as it was blended for application by operators as delivered. Further information on the fluids is listed in Table 9.

Table 9. Test fluid information

Test Fluid	**Manufacturer**	**Brand**	**Appendix**
MIL-PRF-7808	Eastman®	2389®	A
Mil-PRF-23699 Std	Mobil®	Jet Oil II®	A
Mil-PRF-23699 HTS	Mobil®	387®	A
5000 PSI Hyd. Fluid	Eastman®	Skydrol® PE-5	A
3000 PSI Hyd. Fluid	Mobil®	HyJet IV-A Plus®	A
Type 1 Deicing Fluid	Safewing®	MP / LFD 88 Dilute®	A

2.5.4 Studies on oil decomposition temperatures

Kansas State University reviewed test conditions that could be provided by an engine test cell and discussed bleed air delivery temperature ranges from the manufacturer’s engines as KSU determined the most suitable replacement for their Allison C28 engine that failed during the Phase 1 testing campaign. The engine manufacturers design their bleed offtake locations to deliver the lowest temperature and pressure bleed air that is necessary to supply the requirements of the pneumatic systems the engine is designed to run with. Generally, the upper temperature limit of the pneumatic systems currently being supplied is around 315.6℃ (600℉), per discussions with Pratt & Whitney and GE. Larger engines can produce higher bleed air temperatures than most smaller engines. The higher temperature, higher pressure (HP) bleed air is delivered to the pneumatic system through a heat exchanger near the engine that reduces the temperature to around 193.3℃ (380℉), which reduces thermal stress and extends the number of heating and cooling cycles (component life) for the pneumatic and air conditioning heat exchangers. HP Bleed is used to supply pressurized air to the pneumatic system when the aircraft is operating at lower engine power settings, such as ground idle and taxi. The pressures and temperatures would be excessive at high power, so the engine pneumatic control switches the bleed offtake to a lower pressure outlet. On some engines this is called low pressure (LP) bleed, and on others, intermediate pressure (IP) bleed. LP or IP bleed is predominantly utilized during climb-out and cruise. The system switches back to HP bleed at the top of descent when engine thrust is reduced. The HP bleed may supply air temperatures above 300℃ (572℉) for up to 2-minutes prior to switch over to IP bleed (N. Shuaib, Pratt and Whitney personal communication, November 2022).

Thermal decomposition of aircraft turbine oils and hydraulic fluids are minimal in the range of 200℃ (392℉) to 300 C (572℉), but decomposition products have been observed at elevated temperatures between 300℃ (572℉) and 375℃ (707℉). Successful sensors for this project must be able to successfully sense bleed air contamination at the range of temperatures used for most of the engine operating time, 200℃ (392℉) to 300 C (572℉). Ideally, the optimal sensors would also be able to detect bleed air contamination during the brief times when bleed air temperature is elevated above 300℃ (572℉). Laboratory chemical tests utilized have identified a potential range for maximum thermal decomposition to occur around 350℃ (662℉). Several researchers have performed thermal decomposition studies on turbine oils at temperatures above 300℃ (572℉) to try to assess quantities of carbon monoxide generated during thermal decomposition of oils (Crane CR, 1983; Amiri, 2018; van Netten, 2000). Overfelt et al. (2012) reported mass loss began around 200℃ (392℉), and the maximum rate of mass loss occurred at 300.2℃ (572℉), and a peak in gas evolution occurred at 300.8℃ (572℉) for (Eastman) BP Turbo Oil

274, a DEF STAN 91-98 (MODUK, 2001), 7.5 cSt oil for older turboprop applications. They also reported peak degradation temperatures of (Eastman) BP2380®, at 305℃ (581℉), and Mobil Jet Oil II® 307℃ (584.6℉). Both are Standard Class Mil-PRF-23699 oils. They reported Aeroshell Turbine Oil 560®, an HTS oil with a peak degradation temperature of 326℃ (618.8℉).

2.5.5 Range of aircraft bleed air delivery to pneumatic system

2.5.5.1 APU bleed air supply temperatures

The auxiliary power unit (APU) is installed in the tail of commercial passenger aircraft. The bleed duct from the APU conducts hot compressed air from the shaft driven compressor (in most cases), to the cross-over duct between the wings. The APU bleed air temperature is developed through compression, so the bleed air exit temperature is dependent on ambient temperature. The exit temperature can reach approximately 218℃ (425℉) in extreme heat ground operations.

2.5.5.2 Propulsion engine supply temperatures from lower and higher stage bleed air

Extracted bleed air temperatures on current production aircraft propulsion engines can reach 350℃ (662℉) for brief periods of one to two minutes. Future aircraft propulsion engine extraction temperatures are being pushed to higher temperatures as manufacturers strive to increase engine efficiency and reduce oxides of nitrogen (NOx) production levels. Communications with Pratt and Whitney have indicated that bleed air temperatures of 300 ˚C to 350 ˚C can be obtained from the high pressure (HP) port if the HP bleed valve is commanded open at lower power settings. The engine can operate continuously at that power range. The issue for test design is that of protection of the hardware and aircraft systems downstream of the hot bleed extraction port.

2.5.6 Range of bleed air temperature delivery produced by KSU engine testbed

The KSU engine test bed can deliver bleed air temperatures without special modification over a temperature range of 200℃ (392℉) to 260 C (500℉). The test design for the engine test at KSU used the two endpoints for the experimental design, with the upper limit being flexible to accommodate varying upper temperature limits based on daily temperatures at the engine inlet.

2.6 Control blanks

The engine bleed ducting and heat exchanger were cleaned by elevating the temperature of the ducting to the highest bleed air exit temperature possible and removing cooling air to the heat exchanger. This procedure removed lower boiling point compounds that were present in the system. Instrument data and laboratory samples were captured from the system with no contamination present to assess potential background levels of contamination that were not attributable to the contaminant being injected.

2.7 Time lengths

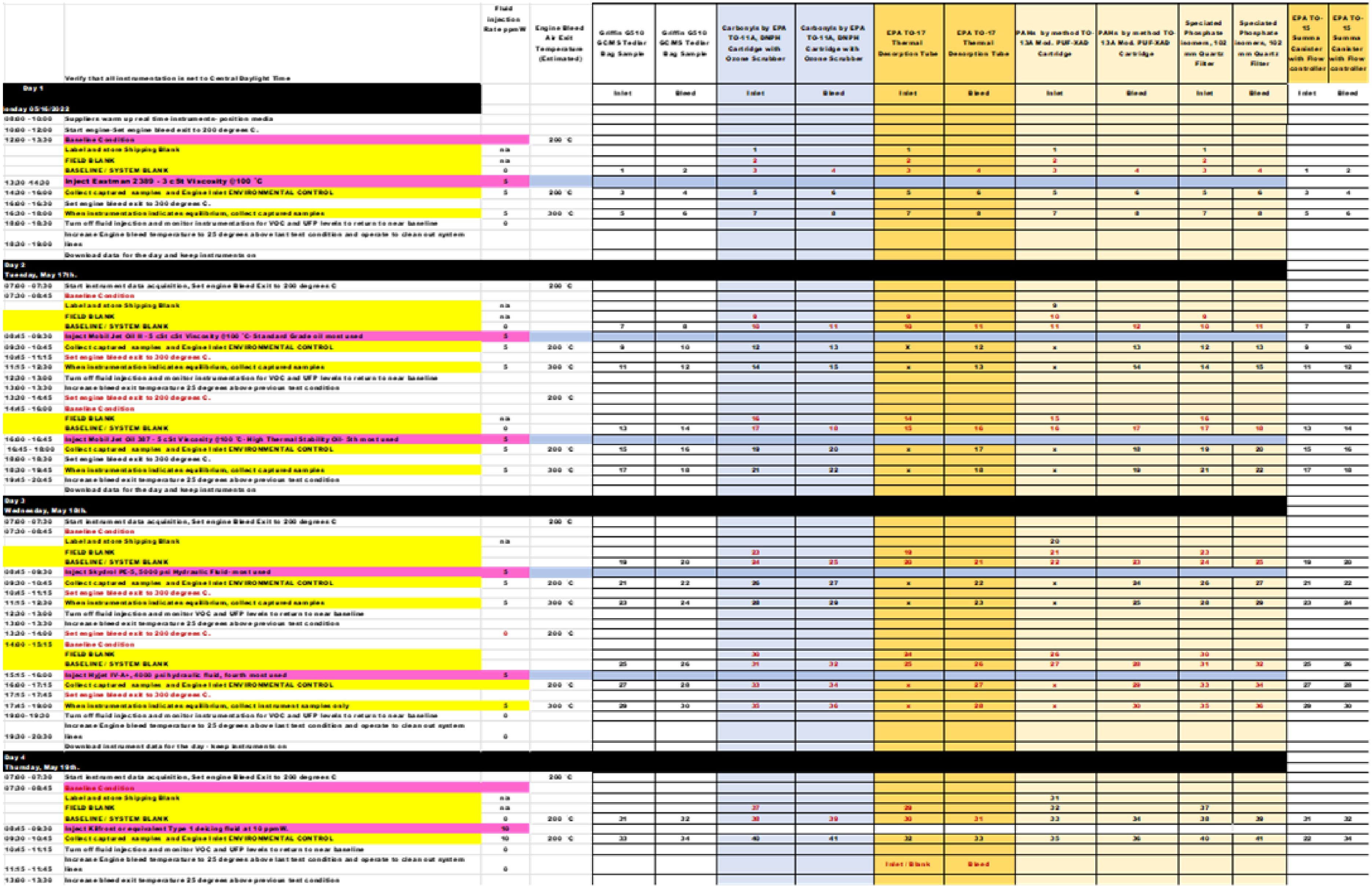
The time required to remain on condition while cleaning ranged from 60 to 90 minutes before the baseline began to stabilize. A period of 60 minutes on condition was utilized while injecting contaminants at the stabilized test condition so that laboratory chemical samples could be acquired. A period of 30 minutes was utilized for capture of TO-11A samples and TO-17 samples.

2.8 Multi-day test plan with contingency

A 4-day test plan with a contingency plan is presented in Figure 37 and Figure 38. Some sample media was late or did not arrive at all, requiring modification of the sampling plan daily. Control samples were measured for instruments and for laboratory chemical sampling. A clean up run and test run were conducted prior to injection of a contaminant fluid. Samples were simultaneously measured for air entering the engine inlet, upstream of the contaminant injection location.

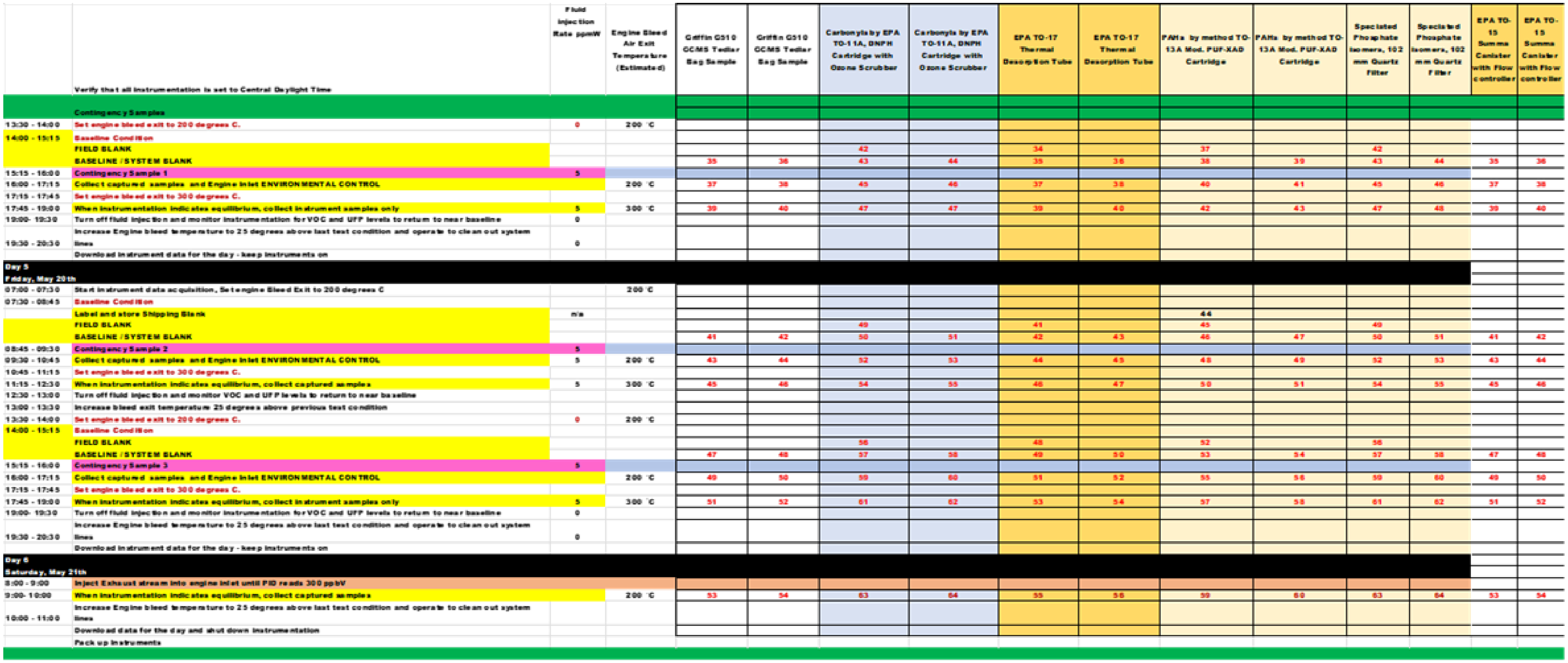
Laboratory chemical blanks consisted of a) an unexposed sample cartridge that traveled with the exposed cartridges, which acted as a shipping blank, b) a sample cartridge that was exposed to air from the system prior to injection, which acted as a system blank, and c) a sample that was exposed at the time of test to air entering the engine. The blanks are necessary so that the contaminants from the system, from travel, and from the analytical lab can be distinguished from contaminants resulting from the fluid injection.

The engine stabilization time was determined by studying prior test results and determining how much time was required for the system to stabilize. The stabilization time was found to range from 15 to 30 minutes, depending on contaminant concentration injected. System cleanup times were found to range from one to two hours of operating with hot bleed air flowing. The time to perform cleanup of the system and to gather baseline data consumed as much and in some cases more time than the time necessary to gather data from contaminant injection. The time on condition for laboratory sampling was ultimately controlled by the Naval Air Warfare Center Aircraft Division (NAWCAD) protocol requiring 60-minute samples for TO-17 thermal desorption cartridges.



		Fluid Injection Rate ppmW	Engine Bleed Air Exit Temperature (Estimated)	Griffin G510 GCMS Tedlar Bag Sample	Griffin G510 GCMS Tedlar Bag Sample	Carbonyls by EPA TO-11A, DNPH Cartridge with Ozone Scrubber	Carbonyls by EPA TO-11A, DNPH Cartridge with Ozone Scrubber	EPA TO-17 Thermal Desorption Tube	EPA TO-17 Thermal Desorption Tube	PAHs by method TO-13A Mod. PUF-XAD Cartridge	PAHs by method TO-13A Mod. PUF-XAD Cartridge	Speciated Phosphate isomers, 102 mm Quartz Filter	Speciated Phosphate isomers, 102 mm Quartz Filter	EPA TO-15 Summa Canister with Flow controller	EPA TO-15 Summa Canister with Flow controller
	Verify that all instrumentation is set to Central Daylight Time														
Day 1				Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed
onday 05/16/2022															
08:00 - 10:00	Suppliers warm up real time instruments- position media														
10:00 - 12:00	Start engine-Set engine bleed exit to 200 degrees C.														
12:00 - 13:30	Baseline Condition		200 °C												
	Label and store Shipping Blank	n/a				1		1		1		1			
	FIELD BLANK	n/a				2		2		2		2			
	BASELINE / SYSTEM BLANK	0		1	2	3	4	3	4	3	4	3	4	1	2
13:30 - 14:30	Inject Eastman 2389 - 3 cSt Viscosity @100 °C	5													
14:30 - 16:00	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	3	4	5	6	5	6	5	6	5	6	3	4
16:00 - 16:30	Set engine bleed exit to 300 degrees C.														
16:30 - 18:00	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	5	6	7	8	7	8	7	8	7	8	5	6
18:00 - 18:30	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline	0													
18:30 - 19:00	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines														
	Download data for the day and keep instruments on														
Day 2 Tuesday, May 17th.															
07:00 - 07:30	Start instrument data acquisition, Set engine Bleed Exit to 200 degrees C		200 °C												
07:30 - 08:45	Baseline Condition														
	Label and store Shipping Blank	n/a								9					
	FIELD BLANK	n/a				9		9		10		9			
	BASELINE / SYSTEM BLANK	0		7	8	10	11	10	11	11	12	10	11	7	8
08:45 - 09:30	Inject Mobil Jet Oil II - 5 cSt cSt Viscosity @100 °C- Standard Grade oil most used	5													
09:30 - 10:45	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	9	10	12	13	X	12	x	13	12	13	9	10
10:45 - 11:15	Set engine bleed exit to 300 degrees C.														
11:15 - 12:30	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	11	12	14	15	x	13	x	14	14	15	11	12
12:30 - 13:00	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline														
13:00 - 13:30	Increase bleed exit temperature 25 degrees above previous test condition														
13:30 - 14:45	Set engine bleed exit to 200 degrees C.		200 °C												
14:45 - 16:00	Baseline Condition														
	FIELD BLANK	n/a				16		14		15		16			
	BASELINE / SYSTEM BLANK	0		13	14	17	18	15	16	16	17	17	18	13	14
16:00 - 16:45	Inject Mobil Jet Oil 387 - 5 cSt Viscosity @100 °C - High Thermal Stability Oil- 5th most used	5													
16:45 - 18:00	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	15	16	19	20	x	17	x	18	19	20	15	16
18:00 - 18:30	Set engine bleed exit to 300 degrees C.														
18:30 - 19:45	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	17	18	21	22	x	18	x	19	21	22	17	18
19:45 - 20:45	Increase bleed exit temperature 25 degrees above previous test condition														
	Download data for the day and keep instruments on														
Day 3 Wednesday, May 18th.															
07:00 - 07:30	Start instrument data acquisition, Set engine Bleed Exit to 200 degrees C		200 °C												
07:30 - 08:45	Baseline Condition														
	Label and store Shipping Blank	n/a								20					
	FIELD BLANK					23		19		21		23			
	BASELINE / SYSTEM BLANK			19	20	24	25	20	21	22	23	24	25	19	20
08:45 - 09:30	Inject Skydrol PE-5, 5000 psi Hydraulic Fluid- most used	5													
09:30 - 10:45	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	21	22	26	27	x	22	x	24	26	27	21	22
10:45 - 11:15	Set engine bleed exit to 300 degrees C.														
11:15 - 12:30	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	23	24	28	29	x	23	x	25	28	29	23	24
12:30 - 13:00	Turn off fluid injection and monitor VOC and UFP levels to return to near baseline														
13:00 - 13:30	Increase bleed exit temperature 25 degrees above previous test condition														
13:30 - 14:00	Set engine bleed exit to 200 degrees C.	0	200 °C												
14:00 - 15:15	Baseline Condition														
	FIELD BLANK					30		24		26		30			
	BASELINE / SYSTEM BLANK			25	26	31	32	25	26	27	28	31	32	25	26
15:15 - 16:00	Inject Hyjet IV-A+, 4000 psi hydraulic fluid, fourth most used	5													
16:00 - 17:15	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL		200 °C	27	28	33	34	x	27	x	29	33	34	27	28
17:15 - 17:45	Set engine bleed exit to 300 degrees C.														
17:45 - 19:00	When instrumentation indicates equilibrium, collect instrument samples only	5	300 °C	29	30	35	36	x	28	x	30	35	36	29	30
19:00-19:30	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline	0													
19:30 - 20:30	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines	0													
	Download instrument data for the day - keep instruments on														
Day 4 Thursday, May 19th.															
07:00 - 07:30	Start instrument data acquisition, Set engine Bleed Exit to 200 degrees C		200 °C												
07:30 - 08:45	Baseline Condition														
	Label and store Shipping Blank	n/a								31					
	FIELD BLANK	n/a				37		29		32		37			
	BASELINE / SYSTEM BLANK	0	200 °C	31	32	38	39	30	31	33	34	38	39	31	32
08:45 - 09:30	Inject Kilfrost or equivalent Type 1 deicing fluid at 10 ppmW.	10													
09:30 - 10:45	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	10	200 °C	33	34	40	41	32	33	35	36	40	41	33	34
10:45 - 11:15	Turn off fluid injection and monitor VOC and UFP levels to return to near baseline	0													
11:15 - 11:45	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines	0						Inlet / Blank	Bleed						
13:00 - 13:30	Increase bleed exit temperature 25 degrees above previous test condition														

Figure 37. May 14 through May 19 AM, 2022, Test Plan



		Fluid injection Rate ppmW	Engine Bleed Air Exit Temperature (Estimated)	Griffin G510 GCMS Tedlar Bag Sample	Griffin G510 GCMS Tedlar Bag Sample	Carbonyls by EPA TO-11A, DNPH Cartridge with Ozone Scrubber	Carbonyls by EPA TO-11A, DNPH Cartridge with Ozone Scrubber	EPA TO-17 Thermal Desorption Tube	EPA TO-17 Thermal Desorption Tube	PAHs by method TO-13A Mod. PUF-XAD Cartridge	PAHs by method TO-13A Mod. PUF-XAD Cartridge	Speciated Phosphate Isomers, 102 mm Quartz Filter	Speciated Phosphate Isomers, 102 mm Quartz Filter	EPA TO-15 Summa Canister with Flow controller	EPA TO-15 Summa Canister with Flow controller
	Verify that all instrumentation is set to Central Daylight Time														
	Contingency Samples														
13:30 - 14:00	Set engine bleed exit to 200 degrees C.	0	200 °C												
14:00 - 15:15	Baseline Condition														
	FIELD BLANK					42		34		37		42			
	BASELINE / SYSTEM BLANK			35	36	43	44	35	36	38	39	43	44	35	36
15:15 - 16:00	Contingency Sample 1	5													
16:00 - 17:15	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL		200 °C	37	38	45	46	37	38	40	41	45	46	37	38
17:15 - 17:45	Set engine bleed exit to 300 degrees C.														
17:45 - 19:00	When instrumentation indicates equilibrium, collect instrument samples only	5	300 °C	39	40	47	47	39	40	42	43	47	48	39	40
19:00- 19:30	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline	0													
19:30 - 20:30	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines	0													
	Download instrument data for the day - keep instruments on														
Day 5 Friday, May 20th															
07:00 - 07:30	Start instrument data acquisition, Set engine Bleed Exit to 200 degrees C		200 °C												
07:30 - 08:45	Baseline Condition														
	Label and store Shipping Blank	n/a								44					
	FIELD BLANK					49		41		45		49			
	BASELINE / SYSTEM BLANK			41	42	50	51	42	43	46	47	50	51	41	42
08:45 - 09:30	Contingency Sample 2	5													
09:30 - 10:45	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	43	44	52	53	44	45	48	49	52	53	43	44
10:45 - 11:15	Set engine bleed exit to 300 degrees C.														
11:15 - 12:30	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	45	46	54	55	46	47	50	51	54	55	45	46
12:30 - 13:00	Turn off fluid injection and monitor VOC and UFP levels to return to near baseline														
13:00 - 13:30	Increase bleed exit temperature 25 degrees above previous test condition														
13:30 - 14:00	Set engine bleed exit to 200 degrees C.	0	200 °C												
14:00 - 15:15	Baseline Condition														
	FIELD BLANK					56		48		52		56			
	BASELINE / SYSTEM BLANK			47	48	57	58	49	50	53	54	57	58	47	48
15:15 - 16:00	Contingency Sample 3	5													
16:00 - 17:15	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL		200 °C	49	50	59	60	51	52	55	56	59	60	49	50
17:15 - 17:45	Set engine bleed exit to 300 degrees C.														
17:45 - 19:00	When instrumentation indicates equilibrium, collect instrument samples only	5	300 °C	51	52	61	62	53	54	57	58	61	62	51	52
19:00- 19:30	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline	0													
19:30 - 20:30	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines	0													
	Download instrument data for the day - keep instruments on														
Day 6 Saturday, May 21th															
8:00 - 9:00	Inject Exhaust stream into engine inlet until PID reads 300 ppbV														
9:00- 10:00	When instrumentation indicates equilibrium, collect captured samples		200 °C	53	54	63	64	55	56	59	60	63	64	53	54
10:00 - 11:00	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines														
	Download data for the day and shut down instrumentation														
	Pack up instruments														

Figure 38. May 19 PM through May 23, 2022, Test Plan

2.9 Engine test logs

The engine test and laboratory sample logs are presented by day in appendices B and E. The test logs are in Appendix B. The laboratory chemical sample logs are in Appendix E.

2.10 Master parts list

The master parts list, which is a listing of hardware that was used in the test setup, and which may be useful for future tests, is located in Appendix D.

2.11 Methods summary

The test methods developed enable evaluation of a range of instrumentation. In addition, the laboratory chemical sampling process enabled evaluation of carbonyls, organophosphates, polyaromatic hydrocarbons, and volatile organic compounds (VOCs). The sampling plan was updated daily as sample media was delivered. Some shortages were encountered for the semi-volatile PUF cartridges. However, quartz filters were still obtained for all the test conditions where sample tube shortages existed. There were also insufficient media to acquire engine inlet samples for every bleed air sample. In those cases, a baseline sample was determined to be the next best alternative for evaluating background contamination in the sample media.

Prior experience led to the requirement that all data would be saved daily. Some instruments write over the data daily; therefore, daily capture is the only way to ensure least loss of data. Other systems presented challenges for saving data. One lesson learned is that it is better to turn an analyzer on and record events, rather than create new log files. Another lesson has been that it is better not to switch an analyzer between test locations during a test, as it can be difficult to track the change of location, and to manipulate the data post-test.

3 Results

Sensor instrumentation results will precede chemical laboratory sample results to maintain the sequence of the test plan presentation. A high-level summary of the test plan is presented in Table 10. In addition, an opportunity was provided in February 2022 to perform on-aircraft measurements in collaboration with American Airlines on an A321 aircraft that was scheduled for heavy maintenance. The American Airlines on-aircraft test results are presented in Section 4.

Table 10. High level test plan

Date	**Contaminant**	**Injection Concentration (ppmW)**	**Bleed Air Temp. ˚C**
May 16, 2022	Eastman™2389	5	200 & 260
May 17, 2022	Mobil™ Jet™ Oil II	5	200 & 250
May 17, 2022	Mobil™ Jet™ Oil 387	5	200 & 250
May 18, 2022	Eastman™ Skydrol ® PE-5	5	200 & 250
May 18, 2022	Mobil™ HyJet™ ™ IV-A plus	5	200 & 250
May 19, 2022	Kilfrost DF Plus (80)® Ready to Use	10	200
May 19, 2022	Mobil™ Jet™ Oil II	5	200 & 250
May 20, 2022	Mobil™ Jet™ Oil II	0, 1, 2, 3, 5,10	200
May 20, 2022	Diesel Forklift Exhaust	ingested	200
May 20, 2022	2004 Chevrolet 1500 Gasoline Engine Exhaust (cold catalytic converter)	ingested	200
May 20, 2022	2022 Toyota Tacoma Exhaust	ingested	200
May 24, 2022	Allison 250 Turbine Exhaust	ingested	200

3.1 Engine instrumentation results

Instrumentation results for UFP and PM measurements are presented as comparisons and evaluated for each day of testing.

3.1.1 Particle measurements with UFP and PM instruments

Figure 39 through Figure 44 contain comparisons of the results for the different UFP and PM instruments. **The most important consideration for detection purposes is the relative change in response with contamination as compared to the no-contamination baseline.** The different instruments detect particles over different size ranges so direct comparison of particle concentration measurements is not meaningful. Additionally, different instruments record responses in different units. For these reasons, the data were not converted to common units. The most important consideration for detection purposes is the relative change in response with contamination as compared to the no-contamination baseline and the data are plotted so as to separate the various curves for easy visualization. For reference, the units for the SMPS, APS, and Naneos Partector II are #/cm3. The units for the Piera instrument are #/liter. The modified smoke detectors provide only an uncalibrated raw voltage signal. The raw voltage signal was multiplied by 1 x 10^7 to place the signal levels at a similar level as the particle number from other sensor types.

Table 11 summarizes the total UFP particles/cm^3 observed during the testing of the five fluid contaminants. Figure 39 presents particle data from May 16, 2022, when the contaminant injected was Eastman™ 2389; Monday, May 16th was the only day at which bleed air exit temperatures reached 260 ˚C. The high bleed temperature throughout the remainder of the test did not go above 250 ˚C. The PM data from the APS mirrored the data from the Scanning Mobility Particle Sizer (SMPS). Naneos Partector II data also was in the same range of total particle count as the SMPS. Piera PM measurements also mirrored the SMP, APS, and Corona discharge instruments.

Table 11. Summary of UFP by SMPS from fluids at low and high bleed air temperature

Fluid	**Brand**	**Base Stock**	**UFP @200 ˚C Bleed**	**UFP @ 250 ˚C Bleed**	**UFP @ 260 ˚C Bleed**
		(% W/W)	particles/ cm^3	particles/ cm^3	particles / cm^3
Mil-PRF-7808	Eastman™ 2389	Formulated from synthetic base stocks and advanced technology additives, to provide the combined thermal and oxidation stability properties of commercial Type II lubricants, with the low temperature fluidity characteristics of a 3 cSt oil	1 x 10^5 to 1.65 x 10^6		1.65 x 10^6 to 1 x 10^7
Mil-PRF-23699 Std	Mobil™ Jet™ Oil Jet II	Manufacturer states oil rated to 204 ˚C without breakdown	1 x 10^7	1 x 10^7	N/A
Mil-PRF-23699 HTS	Mobil™ Jet™ Oil 387	Improved Thermal stability over Standard 23699 Oils	1 x 10^7	1 x 10^7	N/A
Type V Aviation Hydraulic Fluid (3000 and 5000 PSI Systems)	Eastman™ Skydrol® PE-5	Tributyl Phosphate, 58-68 % Triisobutyl Phosphate, 8-10% Phenol, isopropylated, phosphate (3:1), 5-<10 triphenyl phosphate ,1.3-1.9 % 7-Oxabicyclo [4.1.0]heptane-3-carboxylic acid, 2-ethylhexyl ester, 5.5-6.5 % butylated hydroxytoluene, 0.1-1 %	No SMPS response. APS response = 100	Noisy SMPS Response likely due to system contamination APS response = 100	N/A
Type IV Aviation Hydraulic Fluid	Mobil HyJet™ IV-A Plus	2,6-DI-TERT-BUTYL-P-CRESOL , 0.1-<1%	No SMPS response	Noisy SMPS Response likely due to	N/A

Fluid	**Brand**	**Base Stock**	**UFP @200 ˚C Bleed**	**UFP @ 250 ˚C Bleed**	**UFP @ 260 ˚C Bleed**
(3000 PSI Systems)		CALCIUM ALKYLNAPHTHALENESULFONATE/ CARBOXYLATE 0.1-<1% PHENOL, ISOPROPYLATED, PHOSPHATE (3:1) [TRIPHENYL PHOSPHATE > 5%], 10<20% TRIBUTYL PHOSPHATE 70-<80%	APS response = 100	system contamination APS response = 100	
AMS 1424/1	Kilfrost DF Plus (80) Ready to Use	Low foaming propylene glycol-based Type I deicing fluid 50% V/V	No SMPS response	N/A	N/A

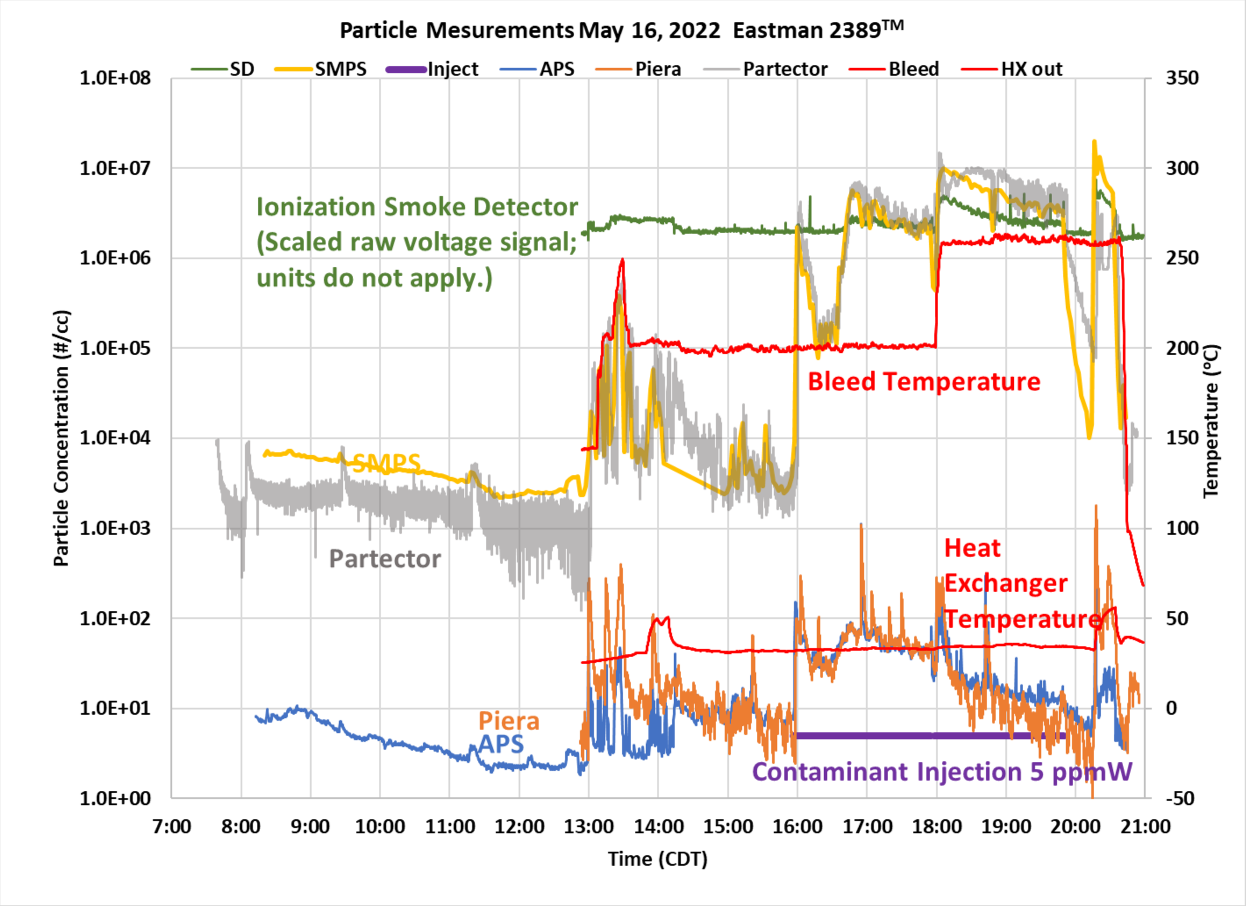


Figure 39. Particle sensor comparison May 16, 2022

The modified smoke detector did not appear to have as great a response, which could be attributed to several factors. The raw voltage signal was multiplied by 1 x 10^7 to place the signal levels of the single chamber ionization sensor at a similar level as the particle number from other sensor types. However, the baseline value of 1 x 10^6 particles could be due to the sensor being a single, rather than a dual chamber smoke detector. Dual chamber smoke detectors were introduced around 50 years ago to minimize known shortcomings of single ionization chamber smoke detectors.

The SMPS indicated that there was an observable increase in UFP when increasing bleed temperature from 200 ˚C to 260 ˚C when injecting five ppmW Mil=PRF-7807 Synthetic Turbine Oil. Concentration appeared to range from 1 x 10^5 to 1.65 x 10^6 particles/ cm^3 at 200 C and 1.65 x 10^6 to 1 x 10^7 particles / cm^3 at 260 C bleed air exit temperature.

Figure 40 depicts the comparison of particle measurements on May 17, 2022, while injecting Mobile Jet II during the morning engine test and Mobil 387 during the engine test. The SMPS results indicated a stable particle concentration during injection of both fluid types, i.e., approximately 1 x 10^7 particles/ cm^3 for MIL-PRF-23699 STD Synthetic Turbine Oil and for Mil-PRF-23699 HTS Synthetic Turbine Oil. There was no observable change in concentration when changing bleed temperature from 200 ˚C to 250 ˚C while injecting 5 ppmW contaminant. The normalized data from the Naneos Partector II shows a decline in total particle count during the 200 ˚C bleed temperature, which Naneos attributed to over-ranging of the UFP on the corona wire. The concentration stabilized at 250 ˚C bleed, and increased during the cleanout phase, when the SMPS total concentration decreased for the Mobil™ Jet™ Oil II. The Naneos Partector II® responded to the concentrations of Mobil 387® at the same level of particles for a 200 ˚C bleed temperature, and decreased when the bleed air temperature was increased to 250 ˚C. This could be evidence of smaller nanoparticles condensing after being heated to the higher bleed air temperature. The concentration of UFP detected by the Naneos Partector II was still the same order of magnitude as the SMPS, which does not negatively impact its ability to be used as an oil bleed air contamination sensor. The Piera Systems follows the same pattern of fine particle count as the APS, indicating that the PM sensors can detect a concentration change at the upper end of the UFP range. The ionization smoke detector had a greater response to Mil-PRF023699 Oils than it demonstrated for the MIL-PRF-7808 oil.

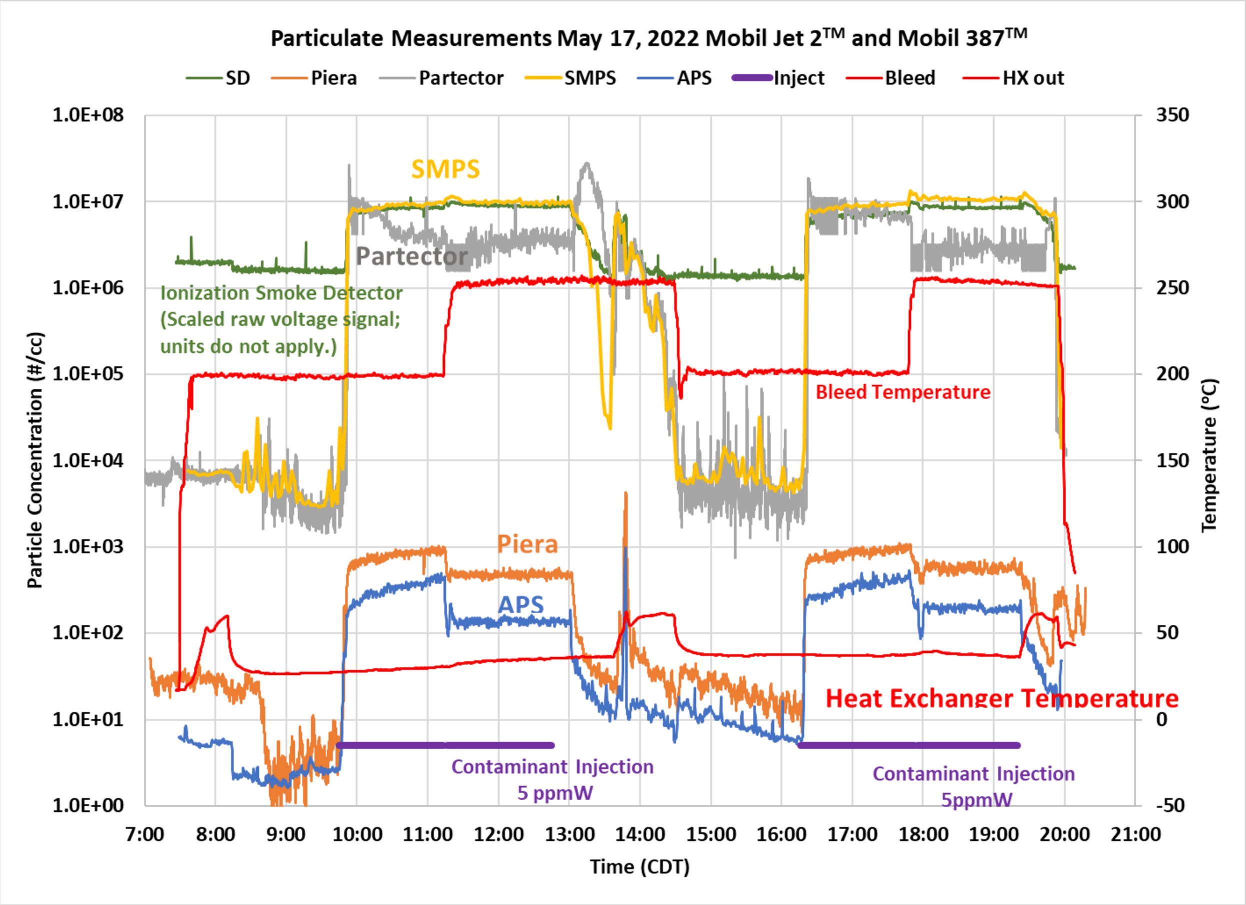


Figure 40. Particle sensor comparison May 17, 2022

Figure 41 presents the observations on May 18, 2022, for Skydrol® PE-5, which was injected in the morning, and for HyJet™ IV-A plus, which was injected in the afternoon. The APS and the Piera Systems showed response to hydraulic fluid. The APS concentration was around 100 particles/ cm^3 for both types of hydraulic fluid and did not appear to change with an increase in bleed air temperature. The SMPS did not show significant response at 200 ˚C bleed but did show a brief response at 250 ˚C and then returned to baseline levels. UFP increased during the cleanout phase, which indicates the SMPS response was likely due to residual contamination in the bleed duct and heat exchanger, and not related directly to the injection of 5 ppmW hydraulic fluid. The ionization smoke detector did not appear to respond to the hydraulic fluids.

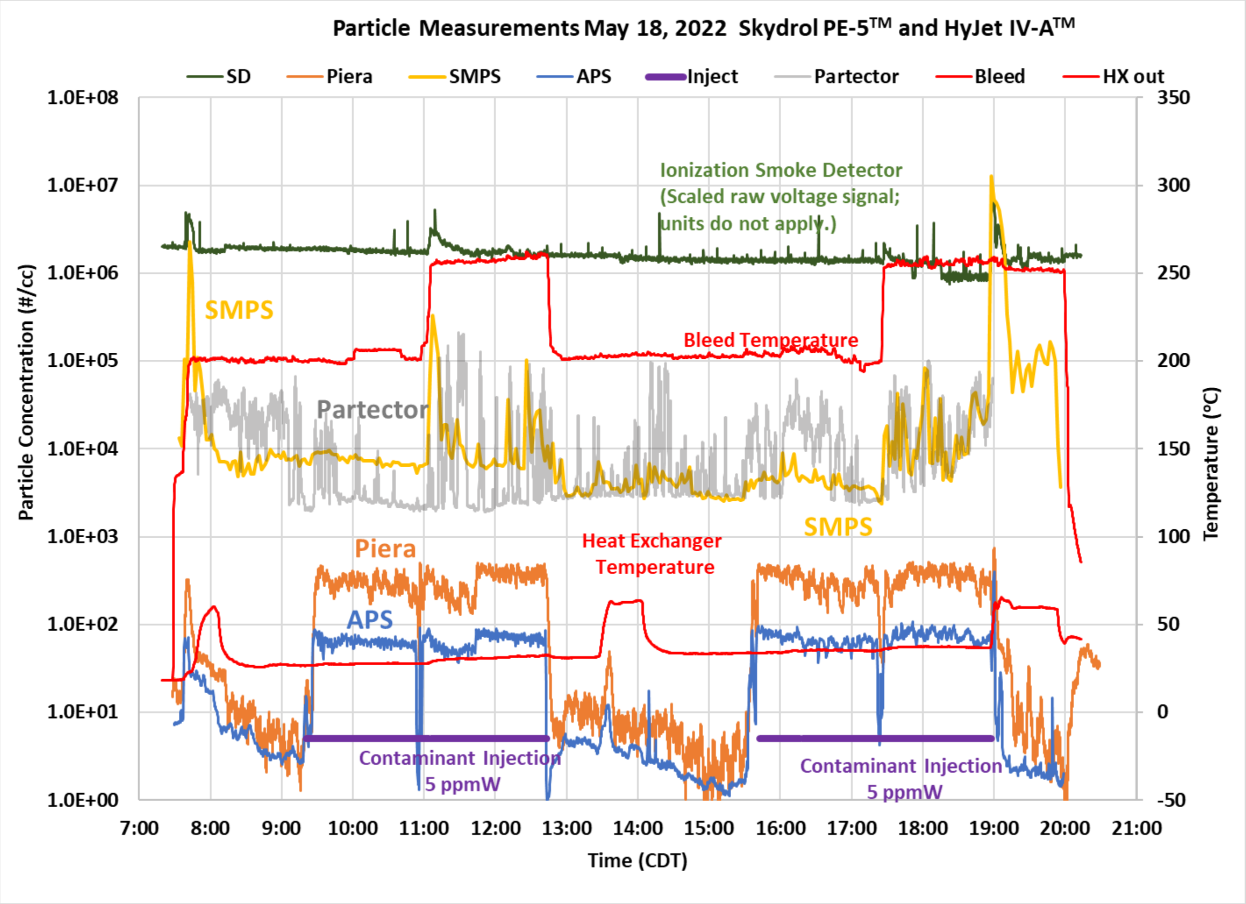


Figure 41. Particle sensor comparison May 18, 2022

Figure 42 provides indication that UFP by SMPS does not respond to deicing fluid. Deicing fluid was only injected at a 200 ˚C bleed temperature, as it would not be present during takeoff/climb bleed air temperatures. The APS and Piera Systems PM sensors did not respond to deicing fluid.

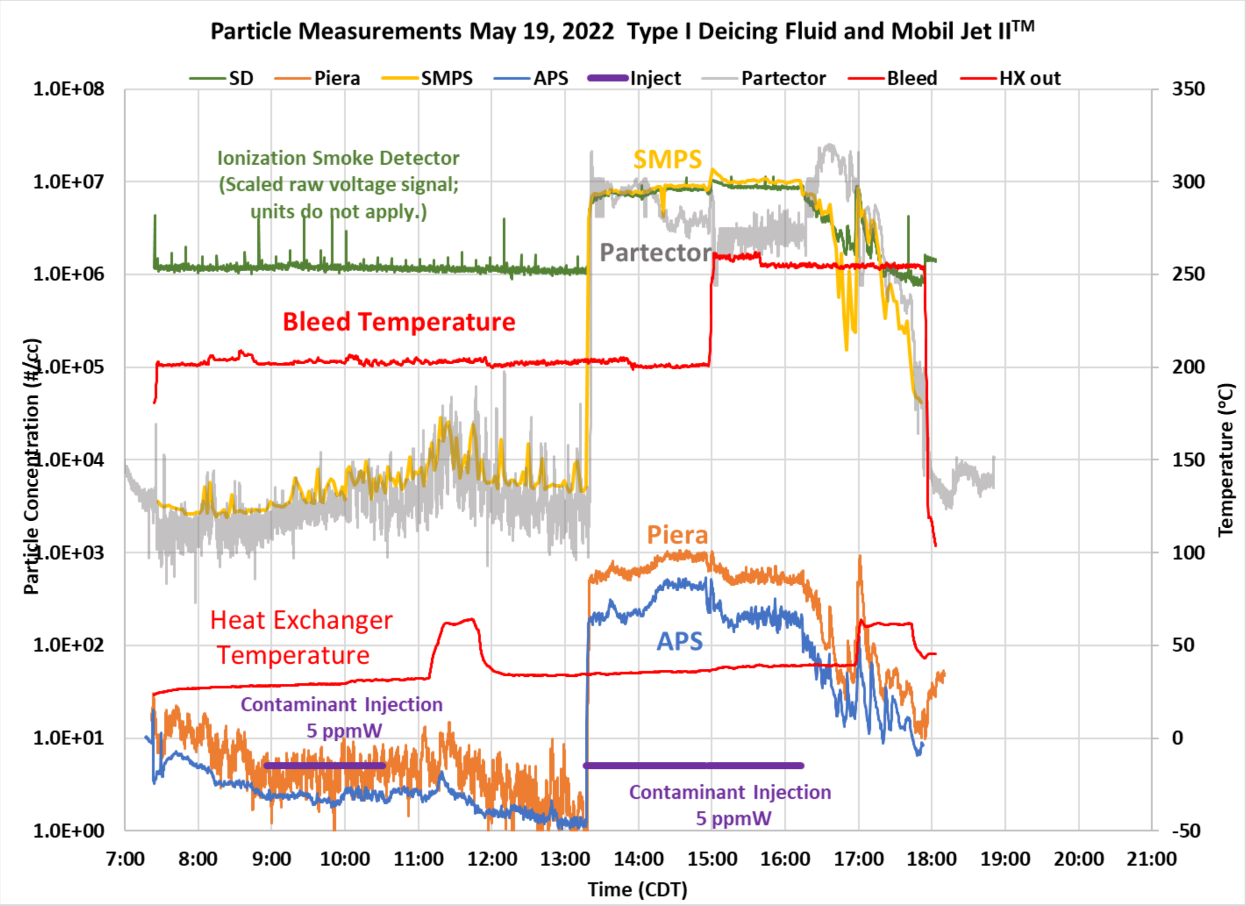


Figure 42. Particle sensor comparison May 19, 2022

A repeat condition for Mobil™ Jet™ Oil II was performed in the afternoon. SMPS response again remained constant at both bleed air temperatures. The particle count was again 1 x 10^7 particles / cm^3. The ionization smoke detector, the APS, and Piera Systems all had similar patterns of their scaled data plots for 5 ppmW Mobil™ Jet™ Oil II.

Figure 43 depicts a stepped injection of Mobil™ Jet™ Oil II from 0 ppmW to 10 ppmW at a constant bleed temperature of 200 ˚C. The SMPS particle count increased from 1 x 10^3 to 1.5 x 10^6 particles/ cm^3 at 1 ppmW concentration and continued to climb to 1 x 10^7 particles/ cm^3 at 10 ppmW. The Naneos Partector II climbed to 1.3 x 10^7 particles/ cm^3 at 1 ppm W, and then decreased to 1 x 10^6 particles/cm^3 at 10 ppmW, due to over-ranging the corona wire. The Naneos

Partector II did appear to recover each time during the clean-up period. Other UFP sensors, including the TSI Nanoscan and the TSI 3007 handheld UFP condensation particle counters do not have the range to measure these levels of UFP without first diluting the sample. Ground vehicle exhaust was ingested in an uncontrolled manner, as depicted in Appendix K. These tests of ground exhaust were used to see if there is significant UFP and PM that could perhaps have a measurable effect on aircraft bleed contaminant measurements if the exhaust were ingested. The levels ingested likely were greater than would be encountered on a flight line, as the exhaust was ducted directly to the engine inlet air supply. Figure 43 indicated a level of 1 x 10 5 particles/ cm3 for UFP from a diesel forklift. Turbine exhaust was ingested from an aircraft engine on May 23, 2022 (Figure 44).

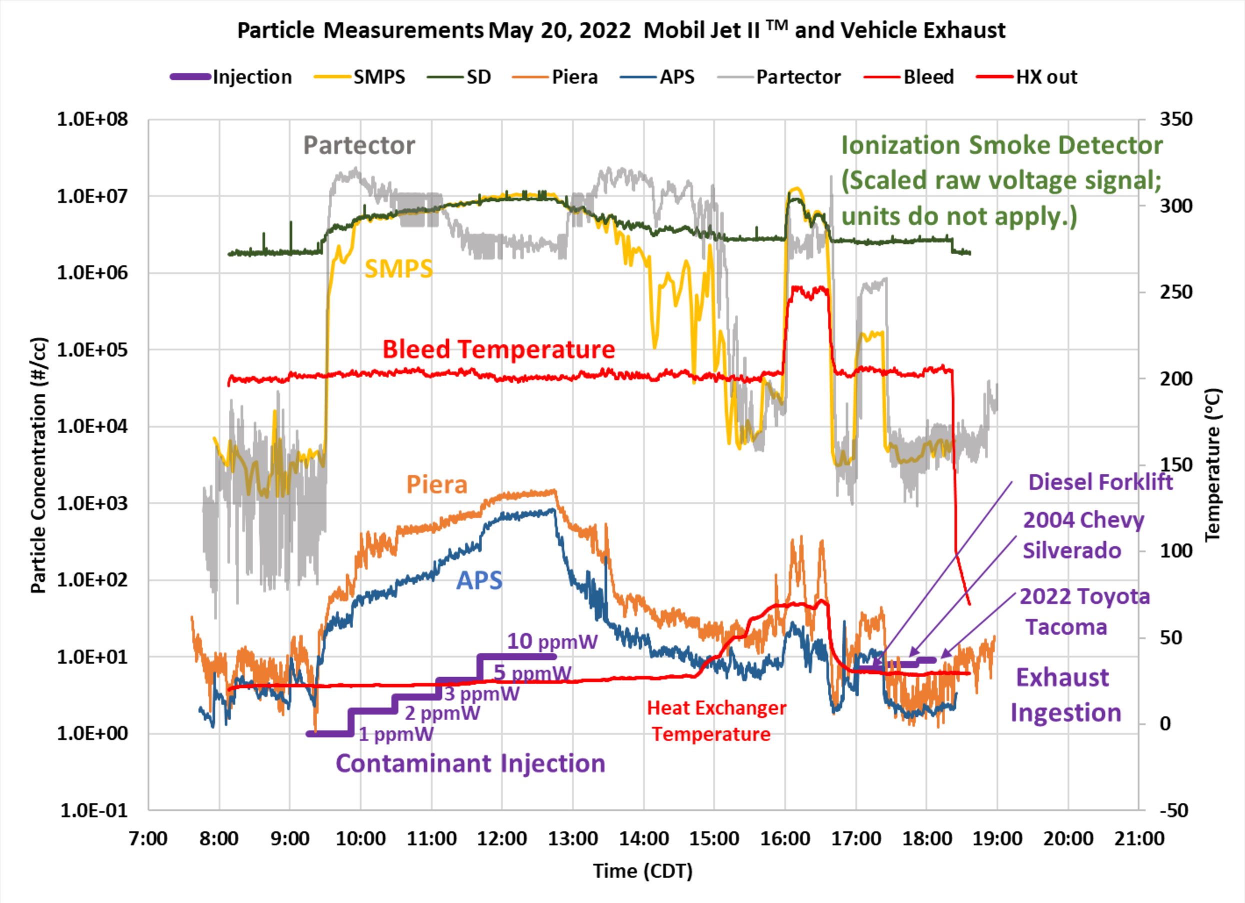


Figure 43. Particle sensor comparison May 20, 2022

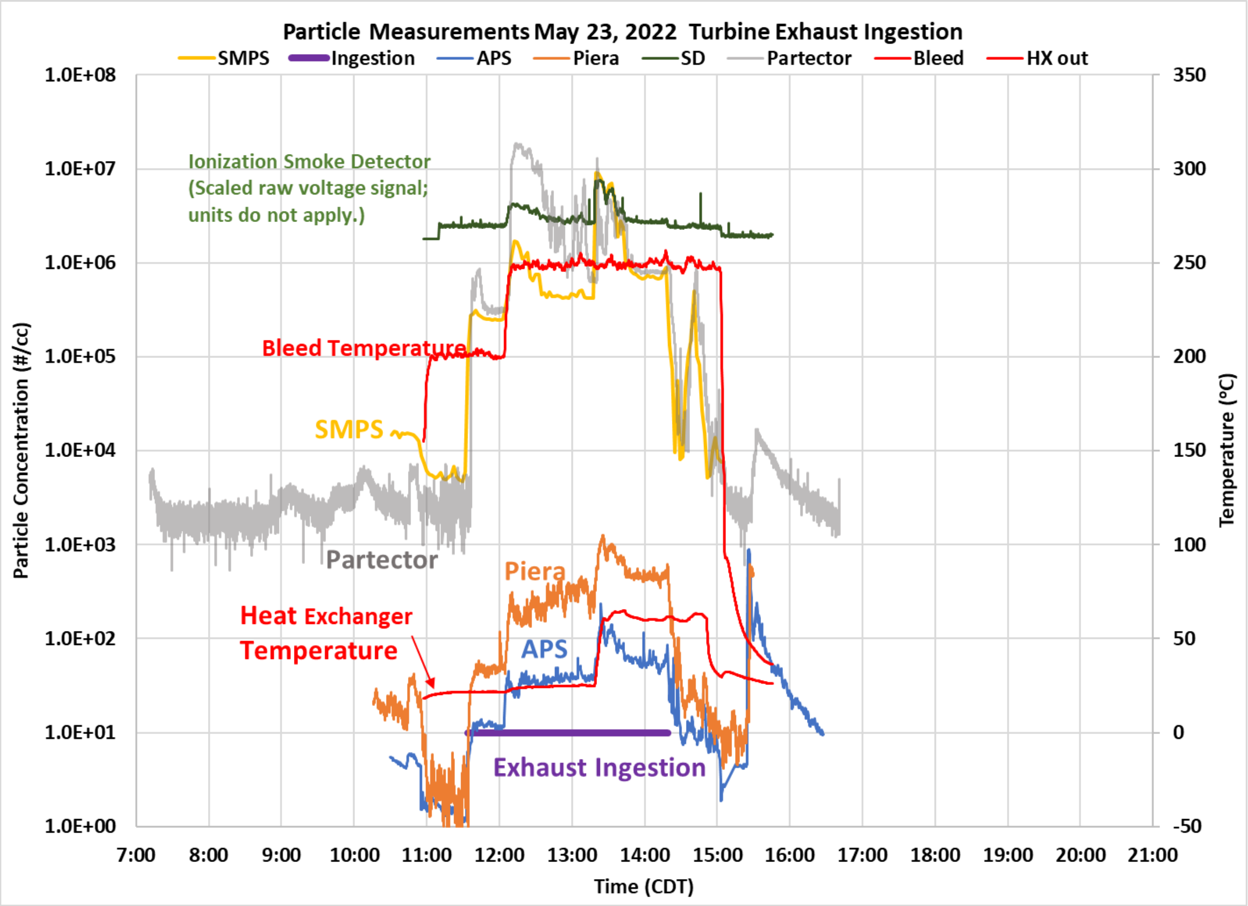


Figure 44. Particle sensor comparison, May 23, 2022

The UFP and PM sensors responded to aircraft turbine engine exhaust that was shunted from the engine exhaust eductor to engine inlet plenum. This shunt is depicted in Appendix K, Figure K-4. The Shunt is circled in red. The use of carbon dioxide as a marker will be discussed later in the results section as a secondary marker to aid in distinguishing oil contamination from exhaust emissions ingestion.

3.1.2 Pegasor PPS-M4 results

Pegasor conducted an online session with KSU on Saturday, May 14th, and concluded that one of the two PPS-M4 units was not performing up to full specifications. They made some online adjustments to the electronics to improve response. The PPS-M4 corona discharge particle sensor has a software package that plots response in real time. There were several pitfalls for the new user that created data loss until the issues were discovered. One unit automatically turned on the corona wire voltage, while the other had to be turned on manually. Due to confusion that arose from the web meeting on the Saturday prior, the assumption was made that corona voltage on both units automatically turned on. In addition, the user must be certain that they have initiated data logging. The PPS-M4 units were installed on the upstream and downstream sides of the bleed air heat exchanger so that total concentration of UFP could be monitored throughout the testing. All data from May 16, 2022, is suspect, due to operator error (Figure 45). Similarly, operator error was still present until the afternoon of May 17, 2022. The corona discharge voltage was turned on at 13:17 hours. A baseline sample with no contaminants, and a sample point with 5 ppmW Mobil 387 was successfully acquired. An increase of UFP at the heat exchanger outlet above the levels in the heat exchanger inlet was observed (Figure 46).

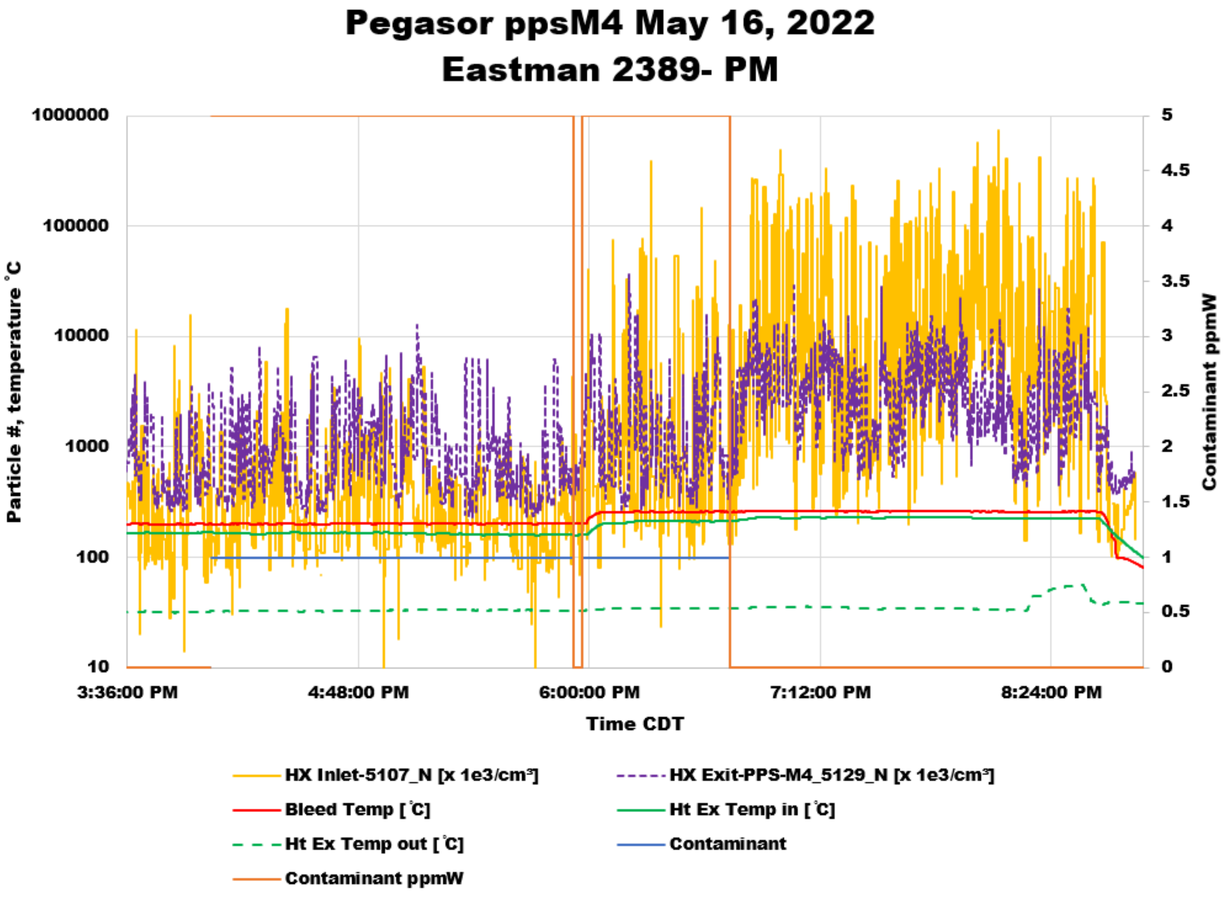


Figure 45. Pegasor PPS-M May 16, 2022

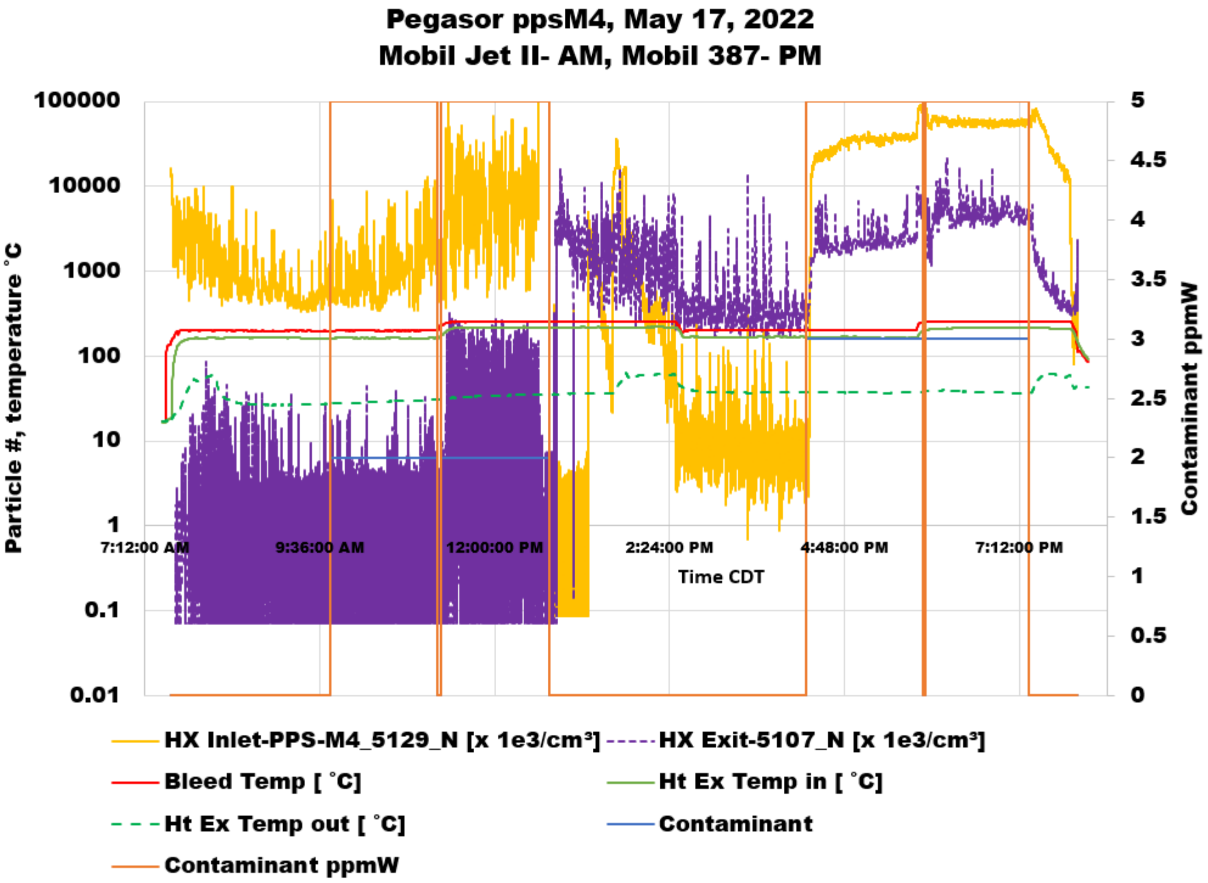


Figure 46. Pegasor PPS-M, Mobil 387 May 17, 2022

The results from instrument operation on May 18, 2022, were also successful and inlet and exit UFP while injecting hydraulic fluids was acquired for Skydrol® PE-5 in the morning, and for HyJet™ IV-A plus in the afternoon. The heat exchanger exit UFP concentrations were greater than the heat-exchange inlet UFP concentrations throughout the entire test (Figure 47).

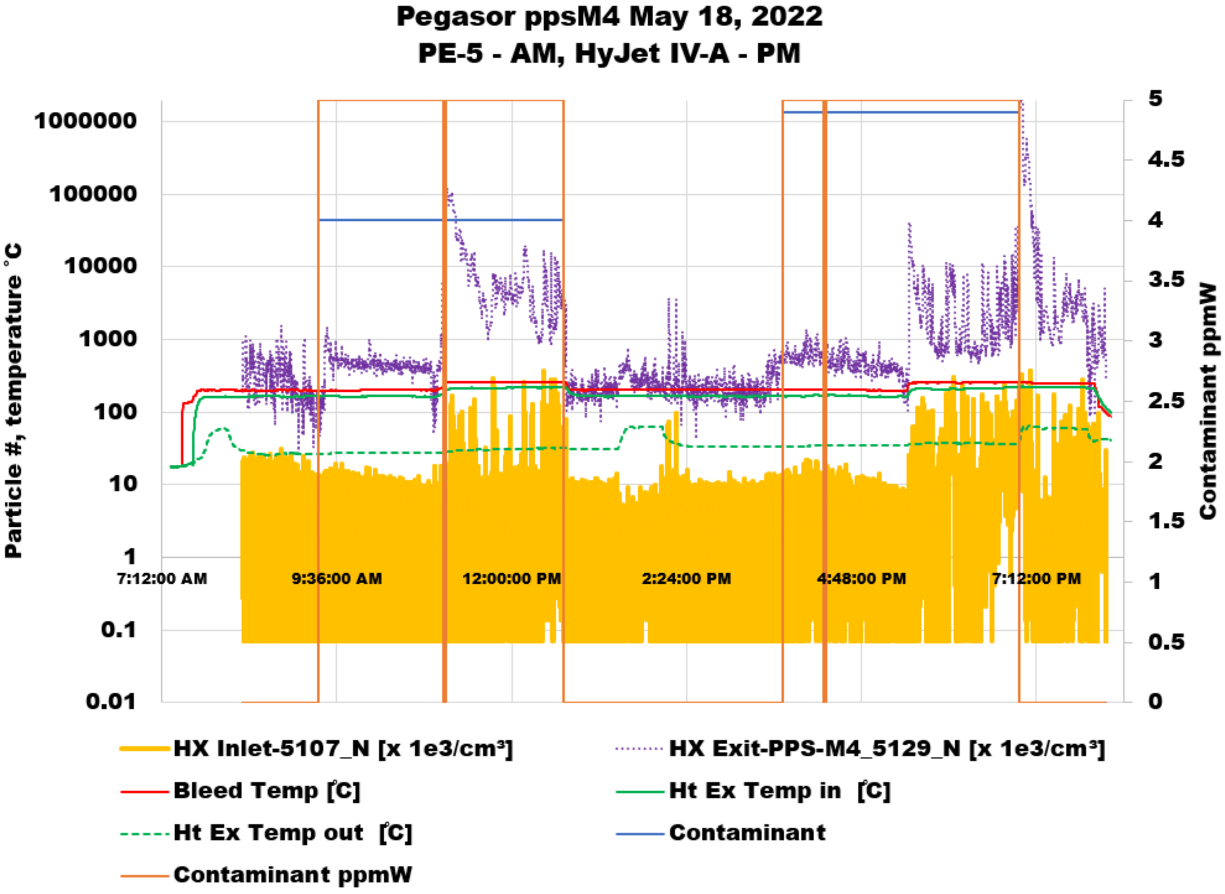


Figure 47. Pegasor PPS-M hydraulic fluids May 18, 2022

Deicing fluid was injected during the morning, and Mobil™ Jet™ II in the afternoon. The results of the sensor responses indicate that UFP levels in the heat exchanger exit were below the UFP levels entering the heat exchanger, while in the afternoon when the Mobil™ Jet™ II sample was injected the UFP level rose to a level greater than the inlet UFP level. This could indicate that condensation is occurring as the air is cooled in the heat exchanger, resulting in the observed increase of UFP (Figure 48).

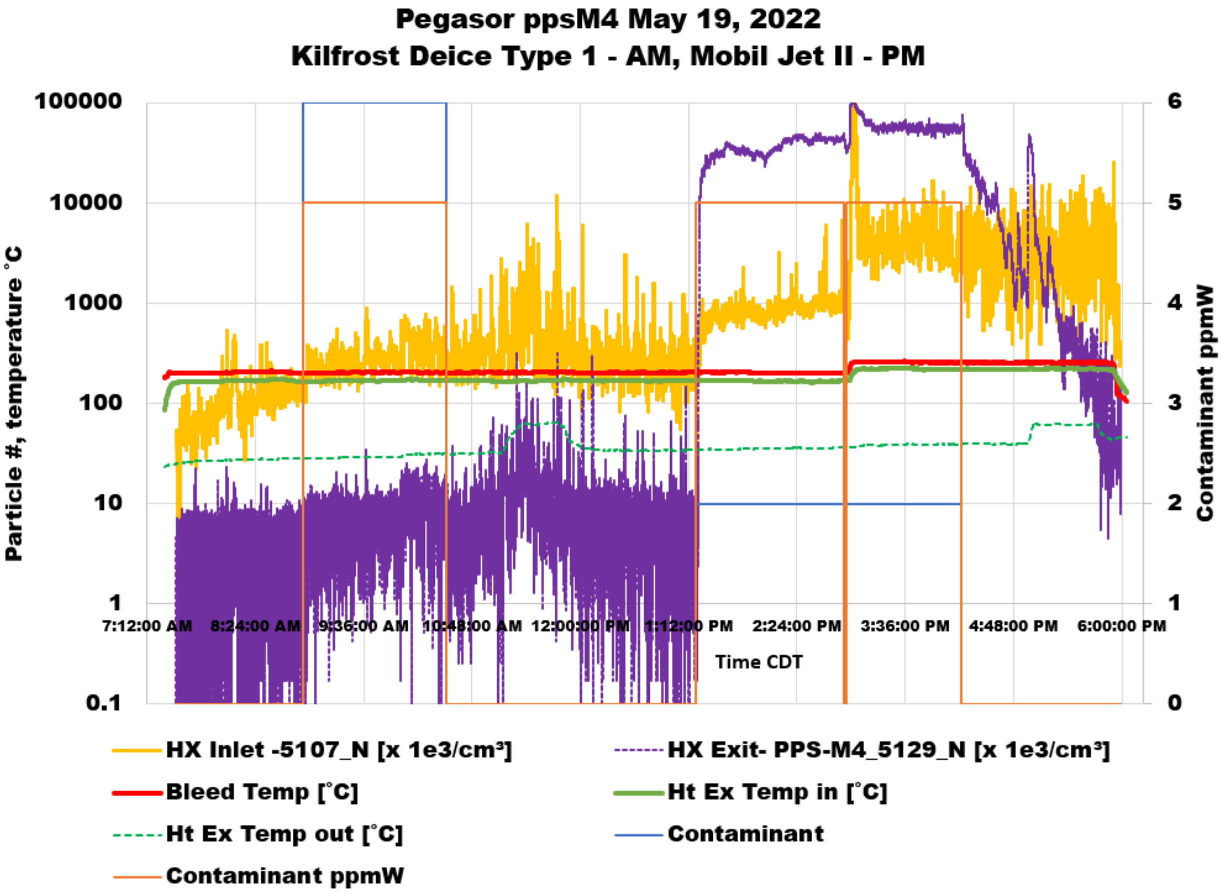


Figure 48. Pegasor PPS-M deicing fluid and turbine oil May 19, 2022

Data acquisition appeared to have not been active until noon on May 20th. The acquisition began during the last 45 minutes of the test where oil was gradually increased from 0 to 10 ppm, so a representative level of UFP at the heat exchanger inlet and exit were measured. The exit concentrations were greater than the inlet for Mobil™ Jet™ II, as was observed for Mobil 387 on May 17th.

The test also showed that UFP concentrations at the heat exchanger exit dropped to levels measured at the heat exchange inlet after one hour of operation with no injection and dropped below inlet levels when the heat exchange temperature was increased. Diesel forklift and automotive exhaust were ingested in the afternoon to simulate contamination on an active airport tarmac. The results from this evaluation indicted that UFP concentration at the inlet of the heat exchanger increase measurably, but that levels at the heat exchanger exit were below the levels entering the heat exchanger and did not increase compared to the non-ingestion levels (Figure 49).

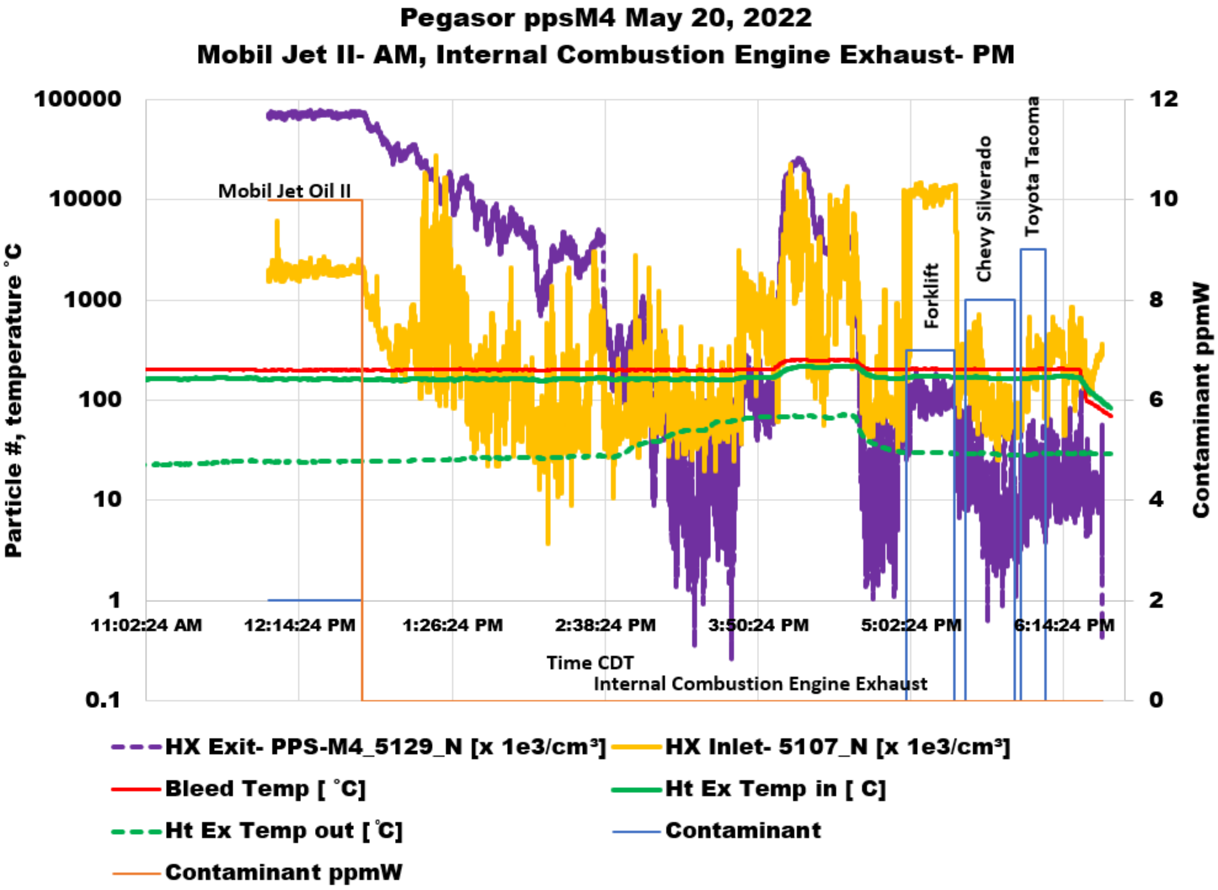


Figure 49. Pegasor PPS-M turbine oil and automotive exhaust May 20, 2022

A small amount of turbine engine exhaust was shunted from the test engine exhaust exit to the exhaust inlet plenum on May 23, 2022. Aircraft engine turbine exhaust measurements, on the other hand, showed increases in UFP at the heat exchanger inlet and heat exchanger exit. The UFP levels at the heat exchanger exit were lower in concentration compared to the inlet (Figure 50). This finding indicates that UFP may not always be a good indicator of turbine exhaust ingestion when measured downstream of the air conditioning packs. Note that all tests of turbine and automotive exhaust were qualitative, and proportions of exhaust were not controlled.

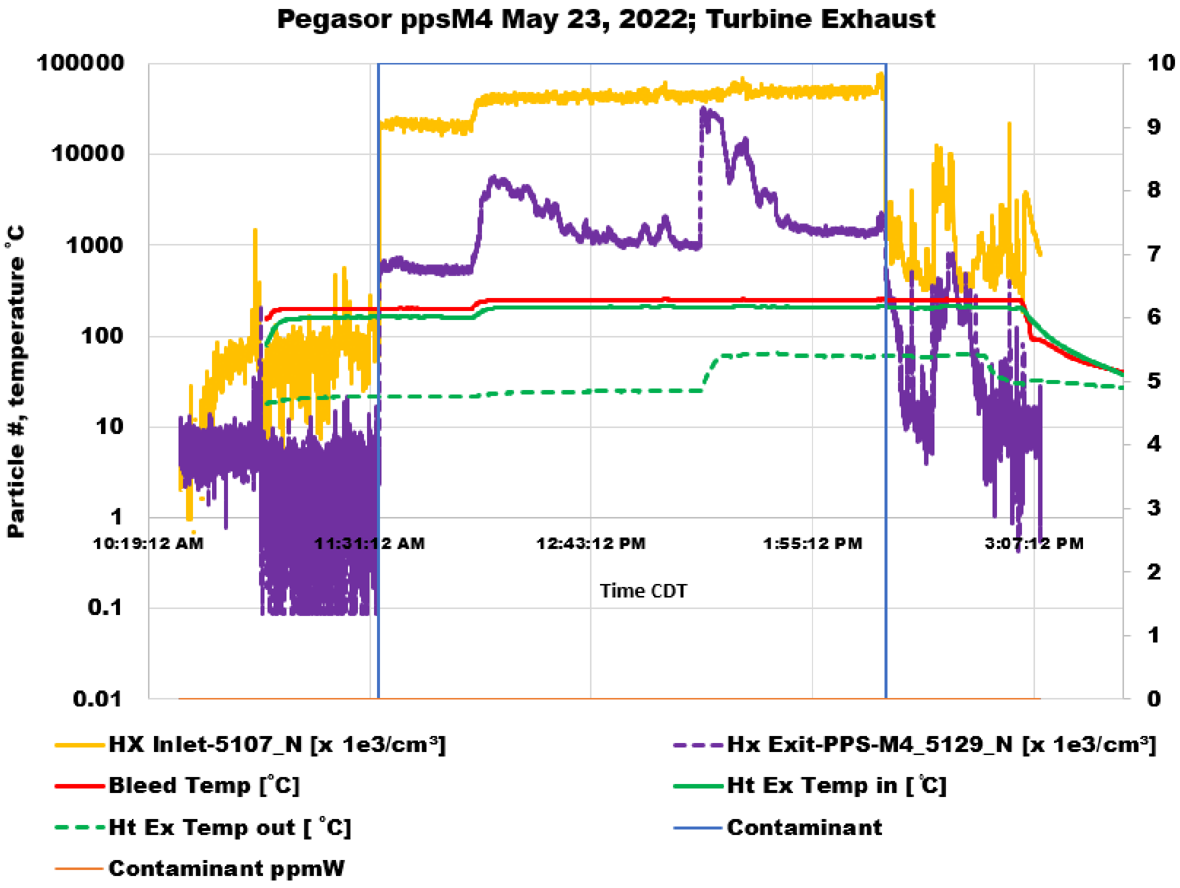


Figure 50. Pegasor PPS-M, aircraft engine turbine exhaust, May 23, 2022

3.1.2.1 Comparative formaldehyde observations

Formaldehyde samples were acquired via Picarro CRDS, several sensors containing electrochemical cells, and laboratory chemical samples that were collected simultaneously during some of the test conditions. Figure 51 shows CRDS and electrochemical cell data gathered on May 19th during injection of 0, 1, 2, 3, 5, and 10 ppm W Mobil™ Jet™ Oil II into the engine inlet. The maximum formaldehyde measured during this test condition with the CRDS was 11.58 ppbV. The electrochemical cells showed minimal response. KSU discussed this with Picarro, Sensirion, and Interscan, and were informed that the electrochemical cells are calibrated with a mixture of formaldehyde in air, so it will not provide a proper response to mixtures of contaminants, such as the mixture being measured at KSU.

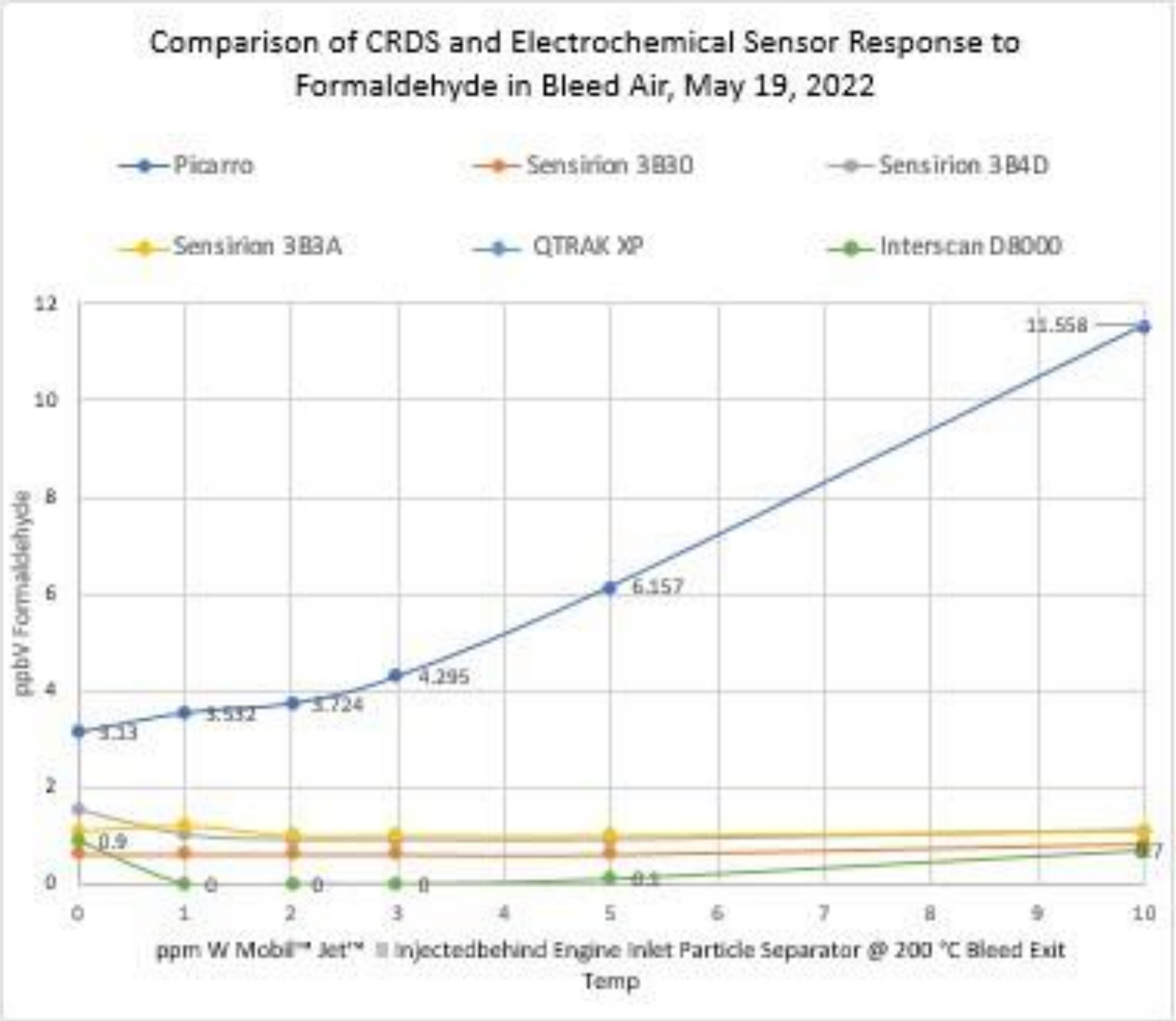


Figure 51. Comparison of CRDS to electrochemical formaldehyde response

Table 12 shows that the electrochemical sensors had mixed responses amongst three Sensirion sensors. In one instance, two of three Sensirion sensors provided an output equivalent to the CRDS sensor.

Table 12. Comparative values of formaldehyde measurement methods (ppbV)

Oil Injected (ppmW)	**Data Point**	**Picarro-Bleed**	**Sensirion 3B30**	**Sensirion 3B4D**	**Sensirion 3B3A**	**QTRAK XP**	**Interscan D8000**	**DNPH Bleed**	**DNPH Inlet**
5	Mobil™ Jet™ II 200C Bleed 17May2022	5.44	1.4	1.9	4.1	-0.16	5.11	6.589	3.67
5	Mobil™ Jet™ II 200C Bleed 19May2022	7.864	1.7	5.2	4.4	-0.13	no data	12.151	11.5
5	Mobil™ Jet™ II 250C Bleed 17May2023	7.453	3.5	7	10.6	-0.14	13.3	20.085	4.70
5	Mobil™ Jet™ II 250C Bleed 19May2023	16.757	1.9	6.2	7.2	-0.12	no data	21.544	11.5
5	Eastman™ 2389 200C Bleed 16May2022	15.161	1.5	4.3	5.7	-0.17	0	8.254	3.51
5	Eastman™ 2389 260C Bleed 16May 2022	10.307	3.1	10.4	13.9	-0.16	0	24.457	3.11
5	Mobil 387 200C Bleed 17May2022	9.676	1.8	6.8	5.8	-0.17	28.4	10.096	8.30
5	Mobil 387 250C Bleed 17May2022	12.064	1.6	4.5	4.3	-0.16	28.2	12.006	5.08
5	Skydrol® PE-5 200C Bleed 18May2022	4.301	1.4	2.1	1.6	-0.16	0	6.775	4.30
5	Skydrol® PE-5 250C Bleed 18May2022	8.699	1.8	2.8	2.9	-0.15	5.9	9.705	7.48
5	HyJet™ IV-A+ 200C Bleed 18May2022	7.423	2.9	2.9	4.5	-0.15	11.2	13.311	11.0
5	HyJet™ IV-A+ 250C Bleed 18May2022	15.693	0.9	2.2	3.9	-0.15	27.9	18.729	8.13
5	Kilfrost Type 1 Deicing Fluid 19May2022	7.198	2	2.6	2.4	-0.11	no data	8.254	6.85
0	Mobil™ Jet™ II 200C Bleed 20May2022	3.13	0.6	1.5	1.1	-0.14	0.9		
1	Mobil™ Jet™ II 200C Bleed 20May2022	3.532	0.6	1	1.2	-0.15	0		
2	Mobil™ Jet™ II 200C Bleed 20May2022	3.724	0.6	0.9	1	-0.15	0		
3	Mobil™ Jet™ II 200C Bleed 20May2022	4.295	0.6	0.9	1	-0.15	0		
5	Mobil™ Jet™ II 200C Bleed 20May2022	6.157	0.6	0.9	1	-0.15	0.1		
10	Mobil™ Jet™ II 200C Bleed 20May2022	11.558	0.8	1.1	1.1	-0.13	0.7		

Some contaminants can cause a negative response in an electrochemical cell, which could offset the positive response from formaldehyde. Acetaldehyde is a contaminant that is also present that should provide a slight positive interference. Unfortunately, no DNPH samples were acquired on May 19, 2022, when the stepwise increase of contaminant was performed.

A separate comparison was made of samples that were acquired by CRDS and laboratory chemical samples for turbine oils and hydraulic fluids. Figure 52 shows comparison of values for Mobil™ Jet™ Oil II at 200 ˚C and 250 ˚C bleed air temperature, and Eastman™ 2387 at 200 ˚C and 260 ˚C.

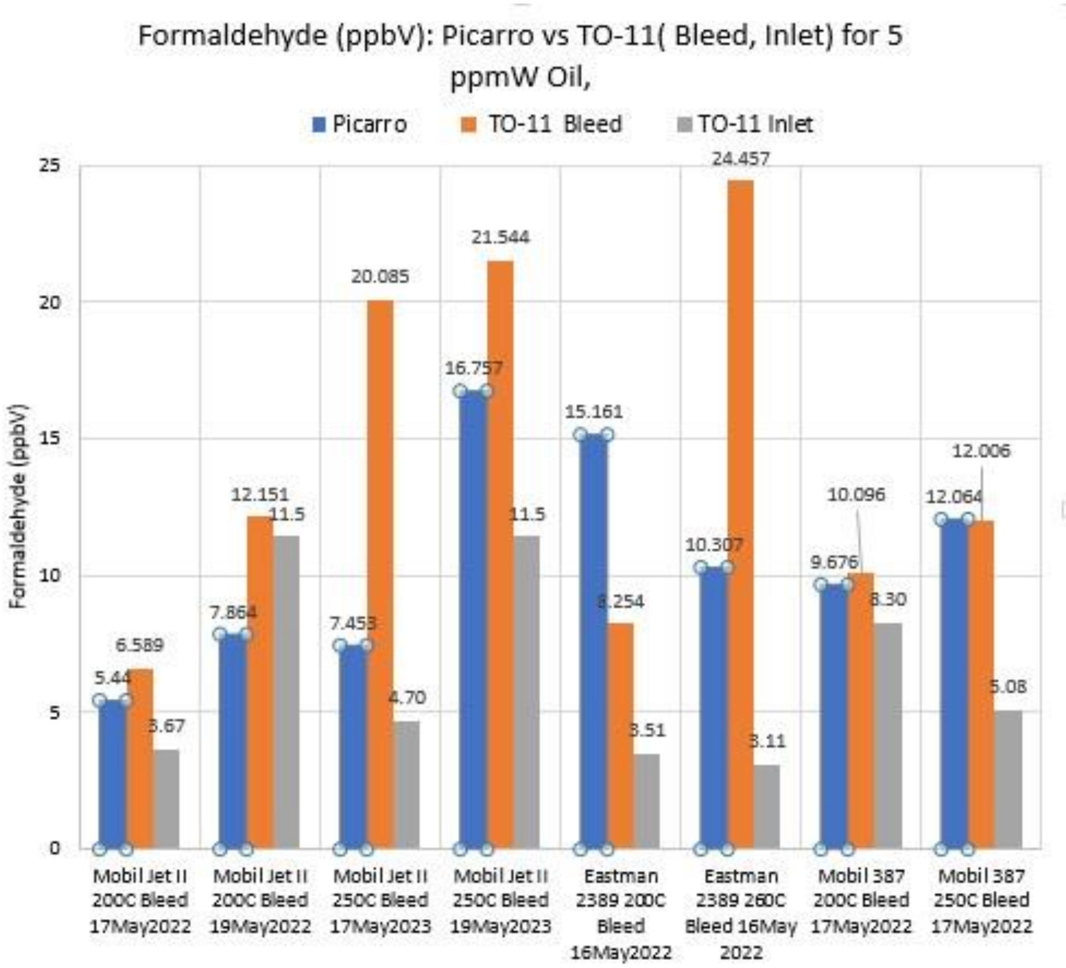


Figure 52. Formaldehyde comparison between DNPH and CRDS methods for turbine oils (ppbV)

Figure 53 shows comparison of values for HyJet™ IV-A plus and Skydrol® PE-5. The values of formaldehyde generated were very low, due to good thermal stability at the test conditions. Reported values for EPA TO-11A were greater than the method minimum detection limit. The Picarro G2307 has a minimum detection limit of 0.3 ppb and zero drift of 1.5 ppbV over a 50-minute average time.

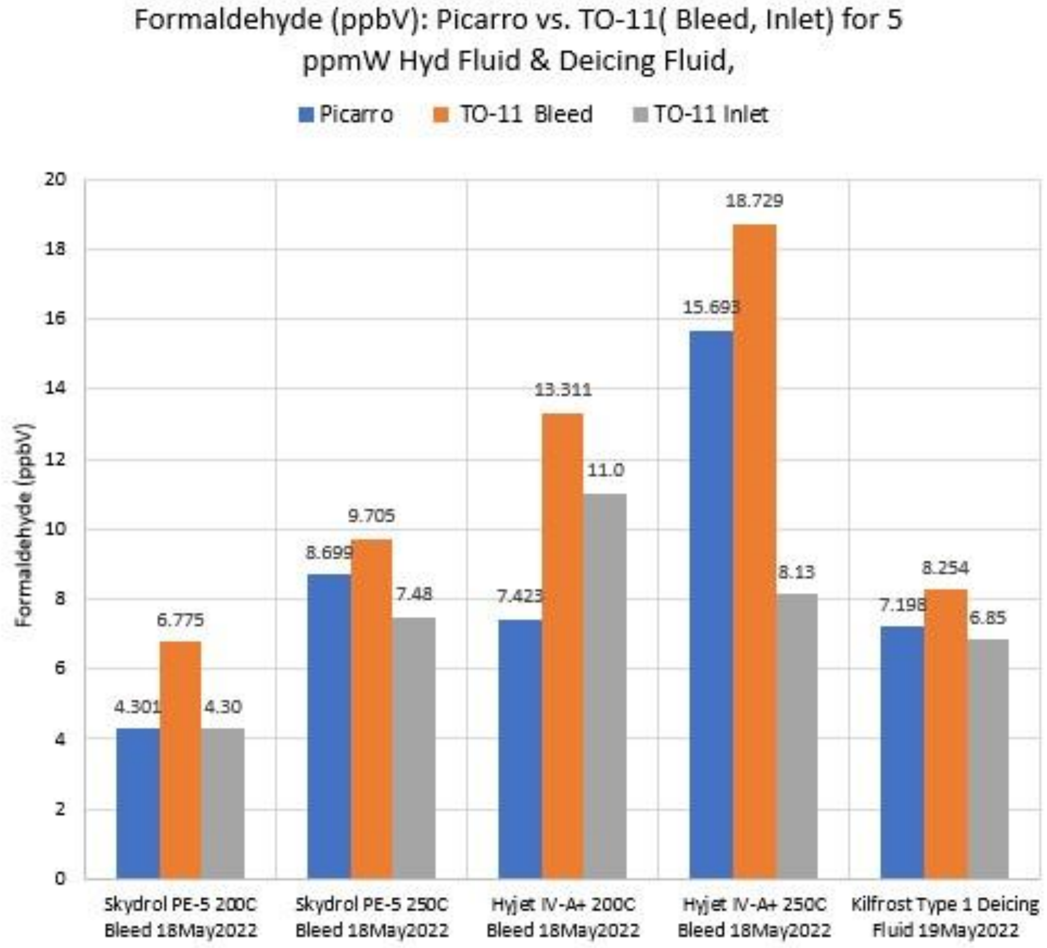


Figure 53. Formaldehyde comparison between DNPH and CRDS methods for hydraulic fluids (ppbV)

In all but one measurement of the oils, the DNPH analysis is greater than the CRDS, and in all samples from the hydraulic fluid test, the uncorrected DNPH results were up to one ppbV higher than the CRDS reported values. The reported values at bleed air temperatures for 5ppmW turbine oil ranged from 5.4 to 16.1 ppbV at 200 C bleed temperature, and from 7.5 to 16.8 ppbV at 250 to 260 C, which indicate that there may be insufficient thermolysis present at the temperatures tested. It may be possible that more formaldehyde production might occur at bleed temperatures more than 300 C. The CRDS reported values for hydraulic fluid ranged from 4.3 to 15.7 ppbV. The DNPH methods ranged from 6.8 to 18.7 ppbV. The inlet DNPH measurements were around 2 ppbV lower than the bleed values at 200 C, and similar results were present at the 250 C test conditions. The formaldehyde measured in the type 1 deicing fluid bleed sample was 7.2 for CRDS and 8.3 for DNPH, and the inlet DNPH was 6.9. This measurement supports the finding from UFP measurements in which little to no UFPs were detected from deicing fluid injections. The electrochemical sensors measurements were not plotted on the chart with the DNPH and CRDS results.

3.1.2.2 Response to raising Heat Exchanger Inlet to 250˚C flowing 5 ppmW Mobil™ Jet™ Oil II

The test setup enabled real time observations of spectrometer and NDIR instrument displays, and during several test conditions, the comparisons were observed to provide very similar patterns of data with distinctly different analytical methods. Images of observations were taken on May 19, 2022, during the test, while injecting Mobil™ Jet™ Oil II and increasing the bleed air temperature setpoint to 250˚C. One interesting observation is that sensors such as the electrochemical sensor, which did not provide response to steady state low levels of contamination, did indicate response during the higher temperature cleanout. Images taken on May 19th around 15:05 pm illustrate this observation. The Picarro cavity ring down spectrometer (Figure 54) peaked around 115 ppbV. The Airsense Aerotracer thick film metal oxide sensor (Figure 55) peaked around 30 units. The three Sensirion developer boards peaked around 30 ppbV Formaldehyde (Figure 56).

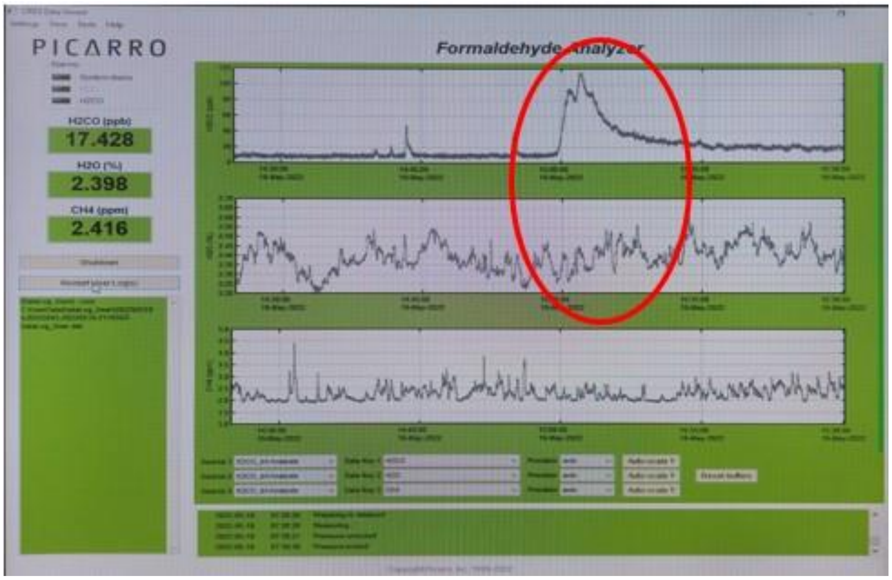


Figure 54. 115 ppbV response of Picarro formaldehyde analyzer to warming bleed air

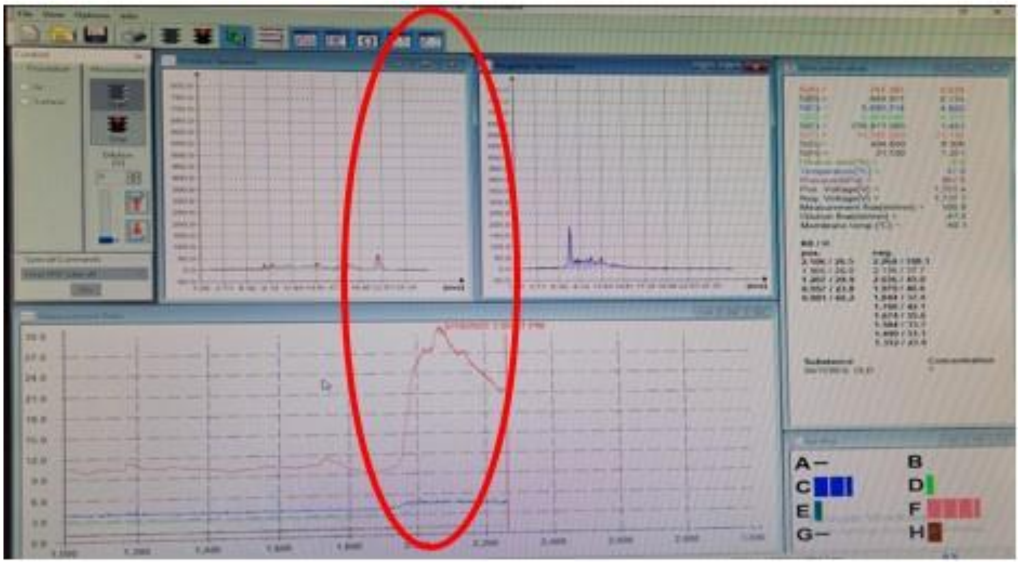


Figure 55. 30-unit response of Aerotracer MOS to warming bleed air

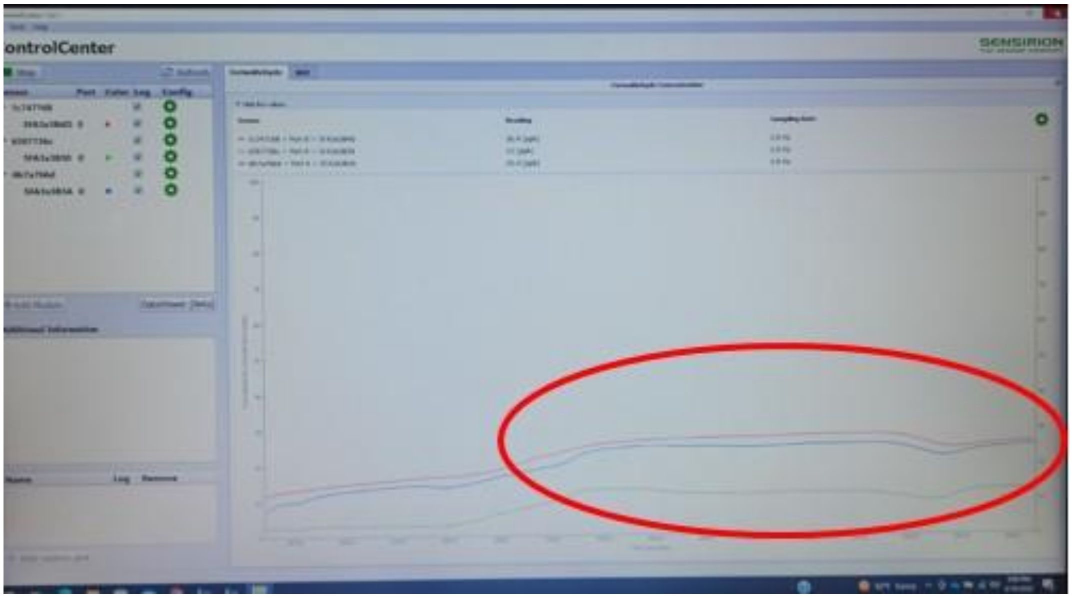


Figure 56. 30 ppbV Sensirion formaldehyde developer board response to warming bleed air

The QTRAK XP® (Figure 57) PID, PM0.3, and CO sensors responded to the transition temperature. The Teledyne 300e low range CO analyzer (Figure 58) indicated a 0.5 ppm increase over the engine inlet CO level. The low range NDIR carbon monoxide sensor indicated an increase of around 647 parts per billion (0.647 ppm) (Figure 58).

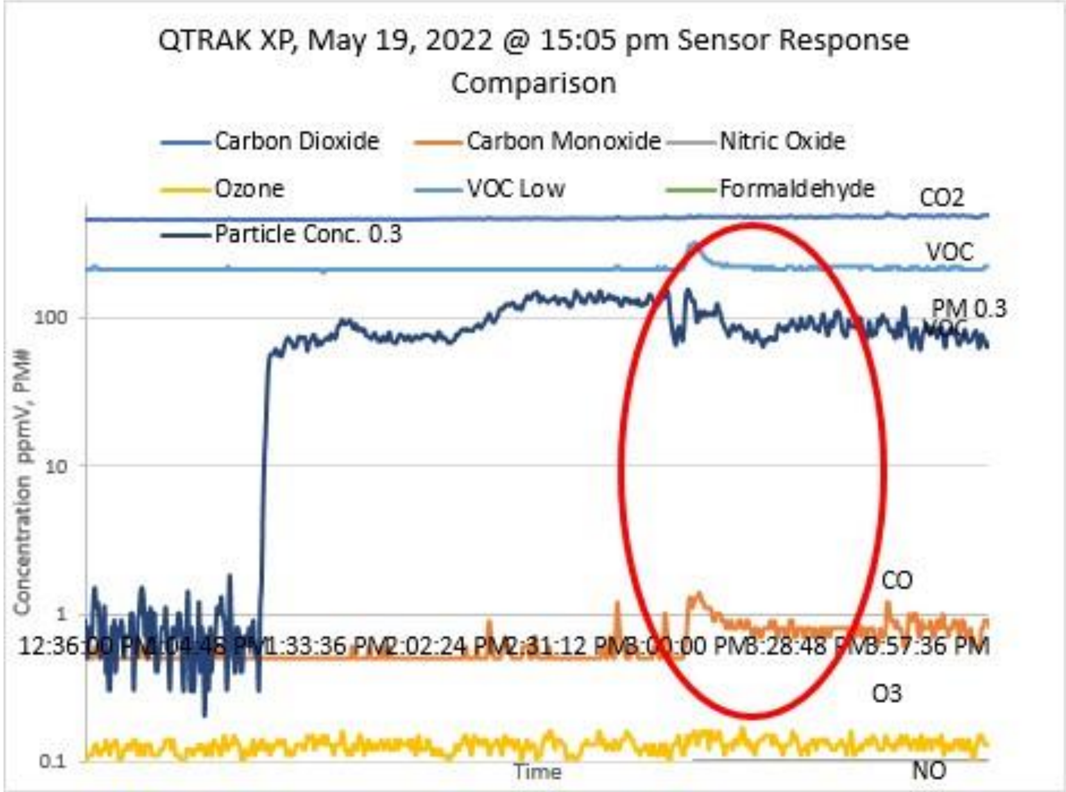


Figure 57. QTRAK XP sensor responses to warming bleed air

Figure 58. 0.6 ppbV response of Teledyne 300e CO analyzer to warming bleed air

The Pegasor PPS-M® (Figure 59) on the heat exchanger exit read over 10,000 e^3 particles per cm^3, while the inlet reading was at the minimum instrument detection level. The Pegasor M3 heat exchanger inlet particle number remained at baseline levels during the transient, while the unit at the heat exchanger exit indicated a level greater than 1 x 10^7 particles per cm3.

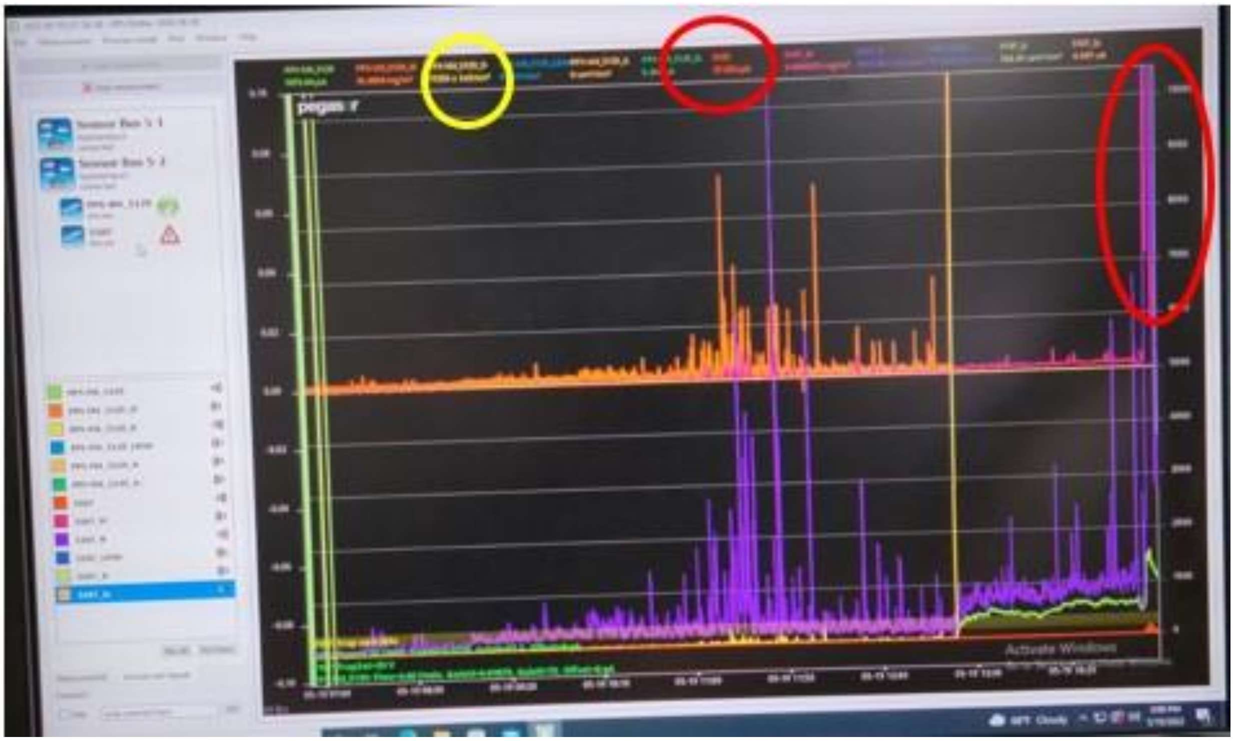


Figure 59. Pegasor PPS-M response at heat exchanger inlet and exit to warming bleed air

Two Teledyne ACES® units (Figure 60) provided the opportunity to compare duplicate sensor modules. PM0.5 particle number (>1000 #/cm3) and VOC by PID (0.2-0.6 ppmV) were the two sensors within ACES that responded during the event on May 19, 2022. CO2 and O2 sensors were stable at atmospheric levels. H2S, SO2, NO, O3 and NO2 sensors remained at their minimum levels. CO readings increased only during the initial injection of Mobil™ Jet™ II, and then stabilized 0.1 to 0.2 ppmV above the level measured during deicing fluid injection and the subsequent clean-out period. Ozone had a negative value during the entire day of testing, but the level of response of the ozone sensor increased by 0.1 ppmV but was still negative. This is likely indicative that the sensor is responding to a chemical other than ozone, and the sensor is either not zeroed, or there is something causing a negative response.

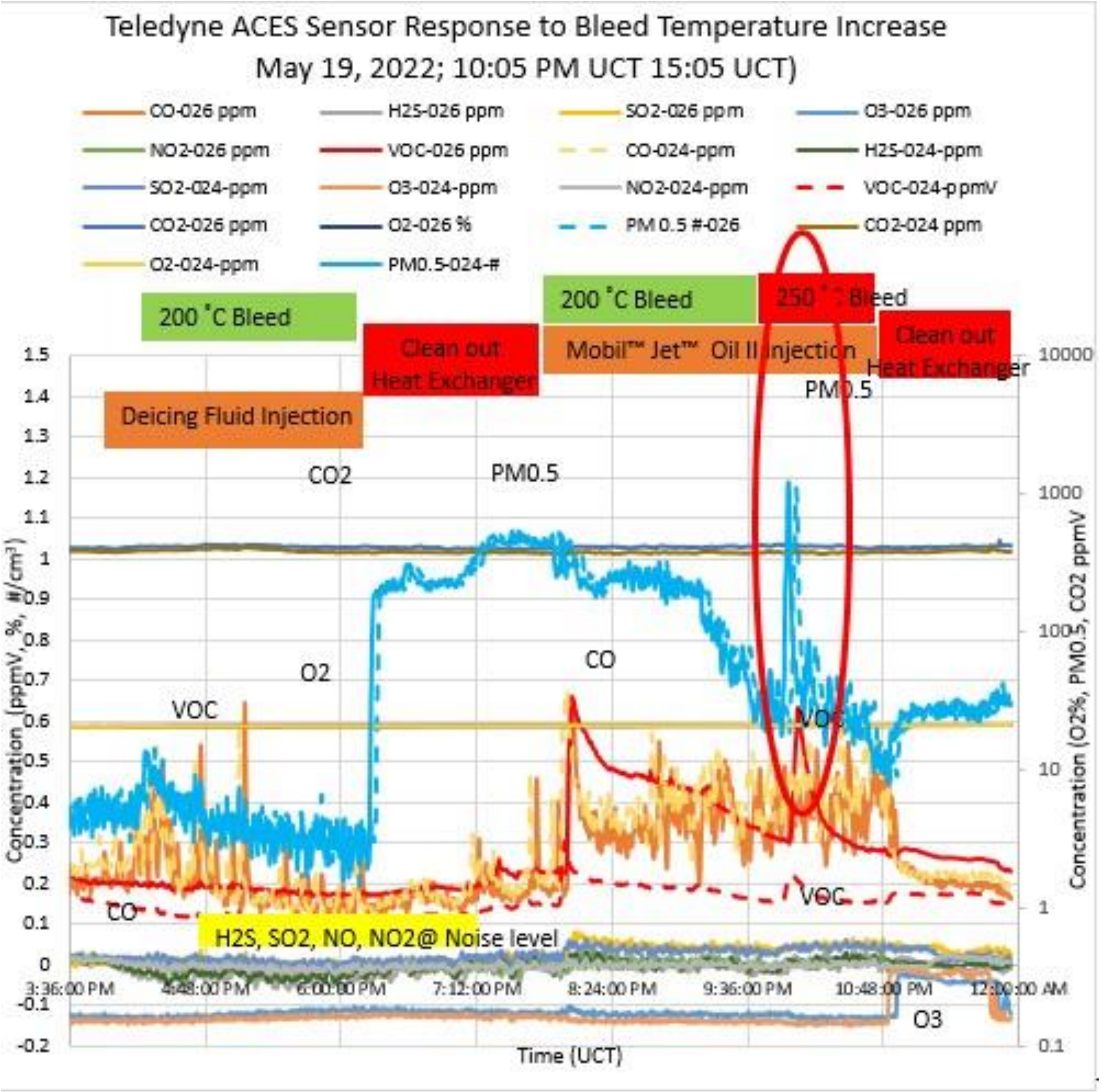


Figure 60. Teledyne ACES sensor response to warming bleed air

The MOKON II® PID (Figure 61) exhibited a small response. The MOKON II that was utilized had a range of 0-20 ppmV Isobutylene equivalents. KSU had desired to utilize a MOKON II with a 0-2 ppmV range, but none were available due to supply chain issues. The low response was perhaps related to the range of the Photoionization Detector (PID) sensor rather than the ability of the PID to detect. This sensor had other measurement issues which could not be resolved with sensor experts at the test. The ppbRAE 3000® PID sensors did show a range of response at the study event. The greatest response was 2.5 ppmV by one sensor and 1 ppmV by a second sensor (Figure 62).

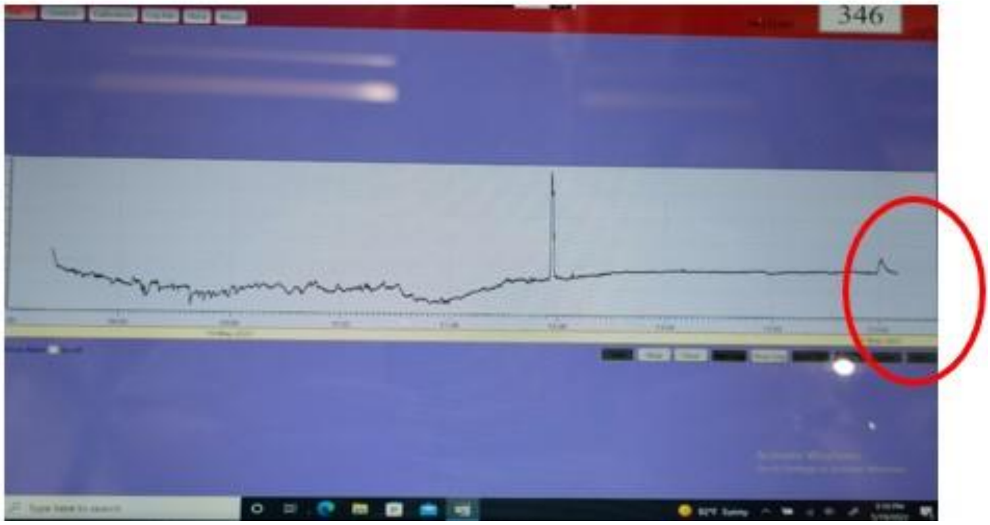


Figure 61. Response of MOKON II PID analyzer to warming bleed air

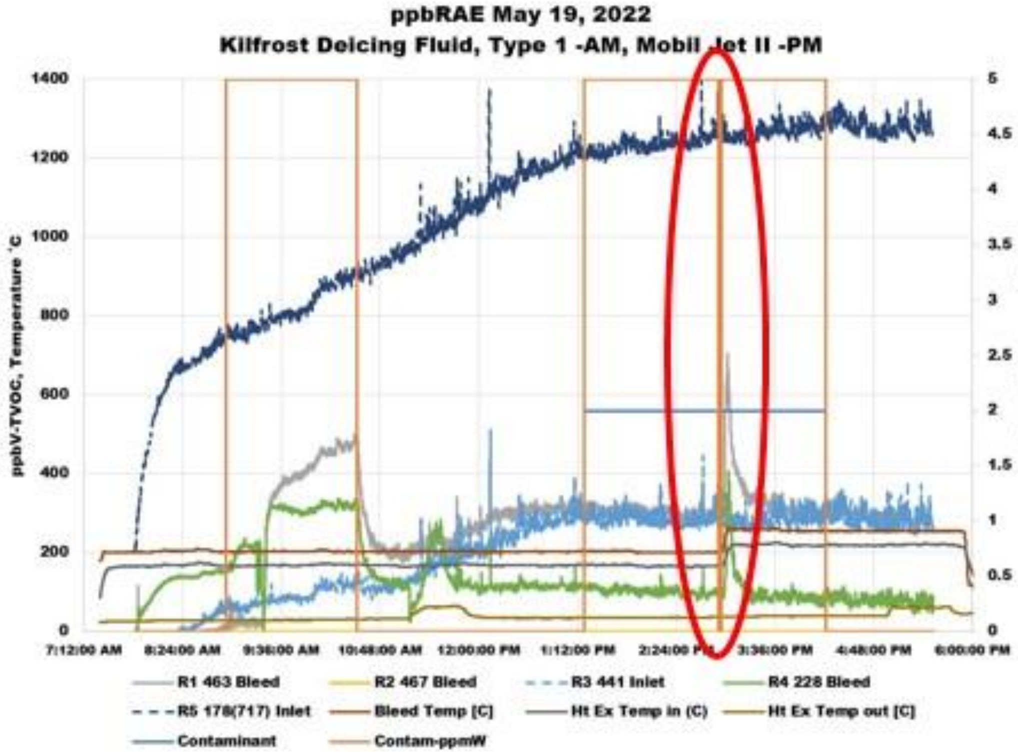


Figure 62. Response of ppbRAE3000 PID analyzer to warming bleed air

The particle measurement data comparison chart for May 19, 2022, was replotted (Figure 63 circled in red) to show the short interval of time during the study event. The SMPS, Naneos II, and Ionization Smoke Detector are included.

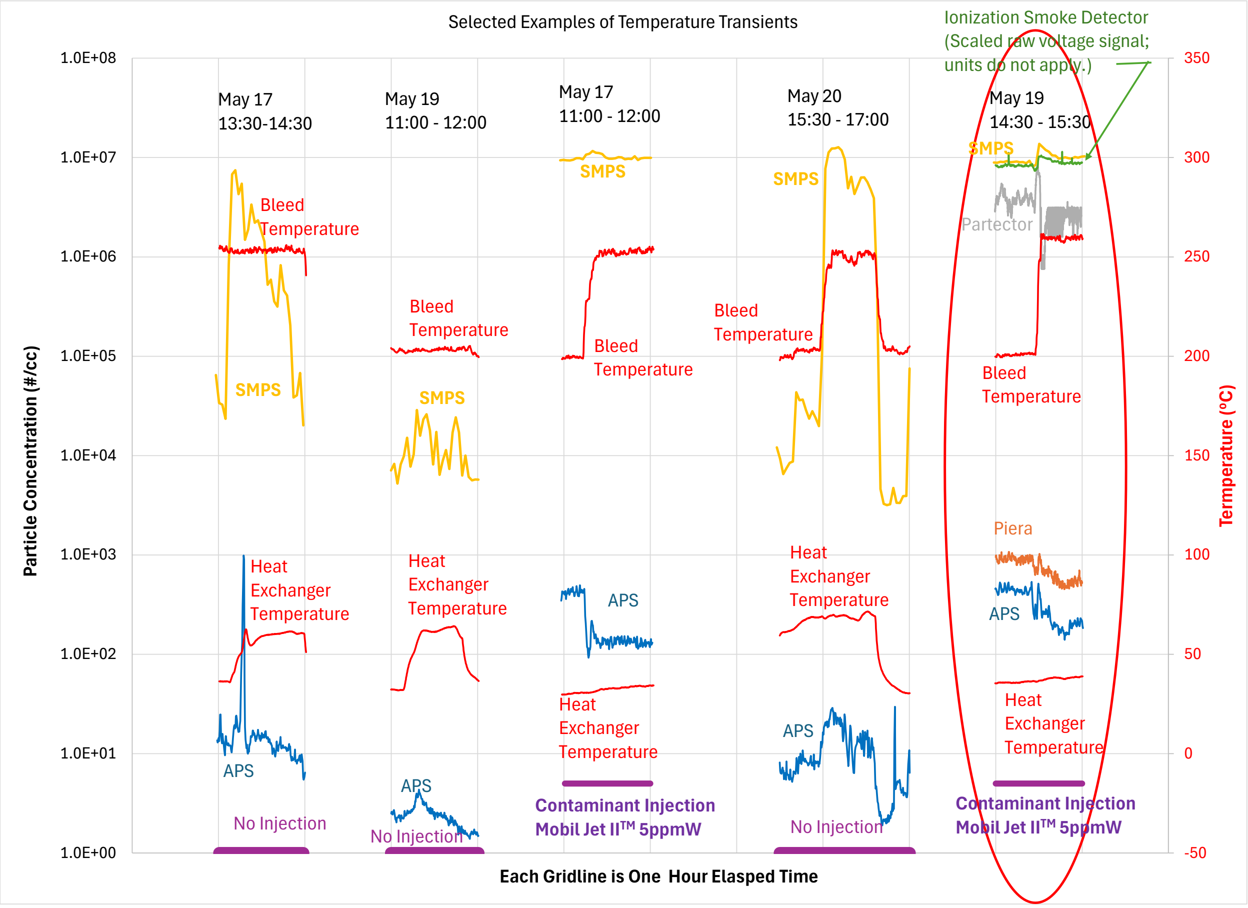


Figure 63. Response of particle analyzers to bleed air temperature transients

The smoke detector showed a slight change during the temperature transition but returned to the original particle counts. The Naneos Partector II showed a greater swing in particle number, which likely is due to depletion of the corona wire charge. The APS and Piera instruments both showed about a 50% decrease in concentration with the increased bleed temperature.

Sensor response during a transient temperature event may be different than what was observed during steady state events as discussed in the comparison of formaldehyde sensor response to laboratory chemical samples. It may be extremely difficult to perform a quantitative calibration of bleed air sensors as the chemical mixture cannot be exactly duplicated. Table 13 summarizes this discussion of sensor performance during the transient event. Figure 63 also includes results for several additional temperature transients. Only the SMPS and APS results are presented for clarity purposes as they characterize the UFP and PM results, respectively. In addition to changes in bleed air temperature, temperature transients were also created by restricting the cooling air to the bleed air heat exchanger which results in an increased exit temperature from the heat exchanger. In addition, bleed air temperatures could change with and without contaminant injection present.

The May 17, 11:00 transient is very similar to the May 19 14:30 transient with the bleed air temperature increasing while oil contamination was present. The responses are very similar, which indicates there is some repeatability in this response. The May 20, 15:30 transient also was a bleed air temperature increase but with no contaminant injection present. In this case there was a very large initial increase in UFP concentration with the concentration reaching values similar to those with 5 ppmW of oil contamination. The concentration then began to decline. A decrease in bleed temperature and heat exchanger exit temperature followed and the UFP concentration dropped to below pre-transient values. Fine particle concentration, as measured by the APS, also increased with the increased bleed temperature for this transient but only by about 50% as compared to the multiple orders of magnitude increase for the UFP.

The May 17, 13:30 and May 19, 11:00 transients were for increases in heat exchanger temperature with constant bleed air temperature. The May 17, 13:30 transient was with approximately 250˚C bleed air and the May 19, 11:00 transient with approximately 200˚C temperature. Interestingly, there was a large increase in UFP of about two orders of magnitude with the higher bleed temperature and minimal increase with the lower bleed temperature. Whether or not this difference is due to the different bleed temperatures or some other factors is not clear. In both cases, there was little effect on the fine particle concentration measured by the APS with small initial increases followed by a decline. The large APS spike with the May 17, 13:30 transient is a single datum point and may be a measurement anomaly. However, it does occur at the same time as a spike in the heat exchanger temperature.

Given the variety of temperature transients and potential combinations with other factors, it is difficult to draw general conclusions about the nature of response that can be expected from temperature transients in the bleed air systems. One important conclusion that can be drawn is that, under the right conditions, bleed air temperature transients and heat exchanger temperature transients can generate temporary UFP concentrations that are comparable to those generated by 5 ppmW of oil contamination. Presumably, the response to temperature transients is due to release of contamination accumulated on surfaces in the compressor or bleed air system. If there is no previous contamination, they might not occur.

Table 13. Summary of transient sensor response during bleed air temperature transient

Analyte	**Sensor Type**	**Manufacturer**	**Model**	**Responded**
Formaldehyde	CRDS	Picarro	G2307	Yes
Formaldehyde	Electrochemical	Sensirion	SFA-30	Yes
Formaldehyde	Electrochemical	TSI	QTRAK XP	No
Methane	CRDS	Picarro	G2307	No
VOC	MOS	Airsense	Aerotracer	Yes
VOC	IMS	Airsense	Aerotracer	Yes
VOC	PID	Honeywell	ppbRAE3000	Yes
VOC-Low	PID	TSI	QTRAK XP	Yes
VOC 0-20 ppm	PID	Ametek	MOKON II	Yes Slight
VOC	PID	Teledyne	ACES	Yes
CO	Electrochemical	TSI	QTRAK XP	Yes
CO	NDIR	Teledyne	300e	Yes
CO	Electrochemical	Teledyne	ACES	No- to event. Yes, to switch from Deicing fluid to Mobil™ Jet™ II
Oxygen	Electrochemical	Teledyne	ACES	No
Ozone	Electrochemical	Teledyne	ACES	No
Ozone	Electrochemical	TSI	QTRAK XP	No
H2S	Electrochemical	Teledyne	ACES	No
SO2	Electrochemical	Teledyne	ACES	No
Nitric Oxide	Electrochemical	TSI	QTRAK XP	No
Nitric Oxide	Electrochemical	Teledyne	ACES	No
NO2	Electrochemical	Teledyne	ACES	No
CO2	NDIR	TSI	QTRAK XP	No
CO2	NDIR	Teledyne	ACES	No
UFP	Corona Discharge	Pegasor	PPS-M	Yes- with a unit on the HX inlets could determine that particles originated from the heat exchanger, not the engine
UFP	Corona Discharge	Naneos	Partector II	Number oscillated and signal noise

Analyte	Sensor Type	Manufacturer	Model	Responded
				increased/oscillated below level at 200 C.
UFP	SMPS	TSI		Yes
UFP	Modified Ionization Smoke Detector	Boise State University		Yes- with normalized baseline @1 x 10^6, Ranged to 1 x 10^7 particles /cm^3
PM0.3 #	Optoelectric	TSI	QTRAK XP	Oscillation, then # dropped slightly
PM0.5 #	Optoelectric	Teledyne	ACES	Number increased to >100, then fell below level at 200 C.
PM	Optoelectric	Piera systems	Canaree	No significant change, but total PM diminished slightly at 250 C.
PM	Aerosol Particle Sizer	TSI	3321	Some oscillation and level diminished and stabilized.

3.1.2.3 Picarro G2307 formaldehyde analyzer response to increasing levels of oil at 200˚C

The Picarro G2307 responded rapidly to changes in concentration of formaldehyde as increasing levels of Mobil™ Jet™ II were injected (Figure 64).

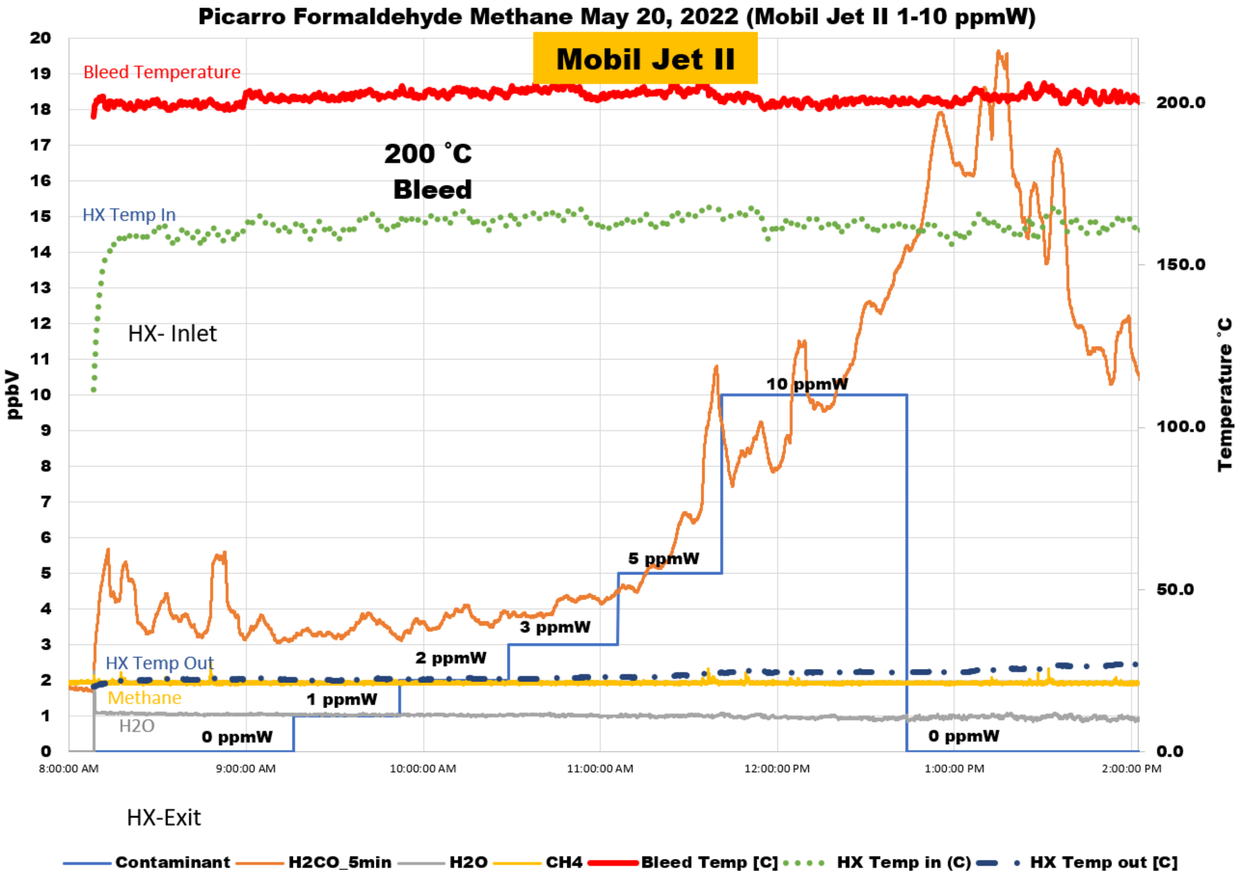


Figure 64. Picarro G2307 CRDS response to increasing levels of oil at 200℃

The response of the Picarro G2307 CRDS to internal combustion engine (ICE) exhaust is presented in Figure 65. The Formaldehyde CRDS exhibited excellent response from single digit to hundreds of ppbV formaldehyde. The data from May 17th indicated a small increase of 4 ppbV formaldehyde when 5 ppmW Mobil™ Jet™ II was injected (Figure 66). Elevating the heat exchanger temperature following Mobil™ Jet™ II injection created higher levels of formaldehyde than sampling through a cool heat exchanger (Figure 66).

This finding would indicate that the heat exchanger could be a secondary source of contaminants when it is heated, in addition to the increased level of UFP mentioned earlier. The formaldehyde level did diminish rapidly when the heat exchanger cooling was turned back on for the Mobil

387 injection. Levels of formaldehyde during Mobil 387 fluctuated by approximately 3 ppbV at 200 ˚C and increased to 8 ppbV at the elevated bleed temperature.

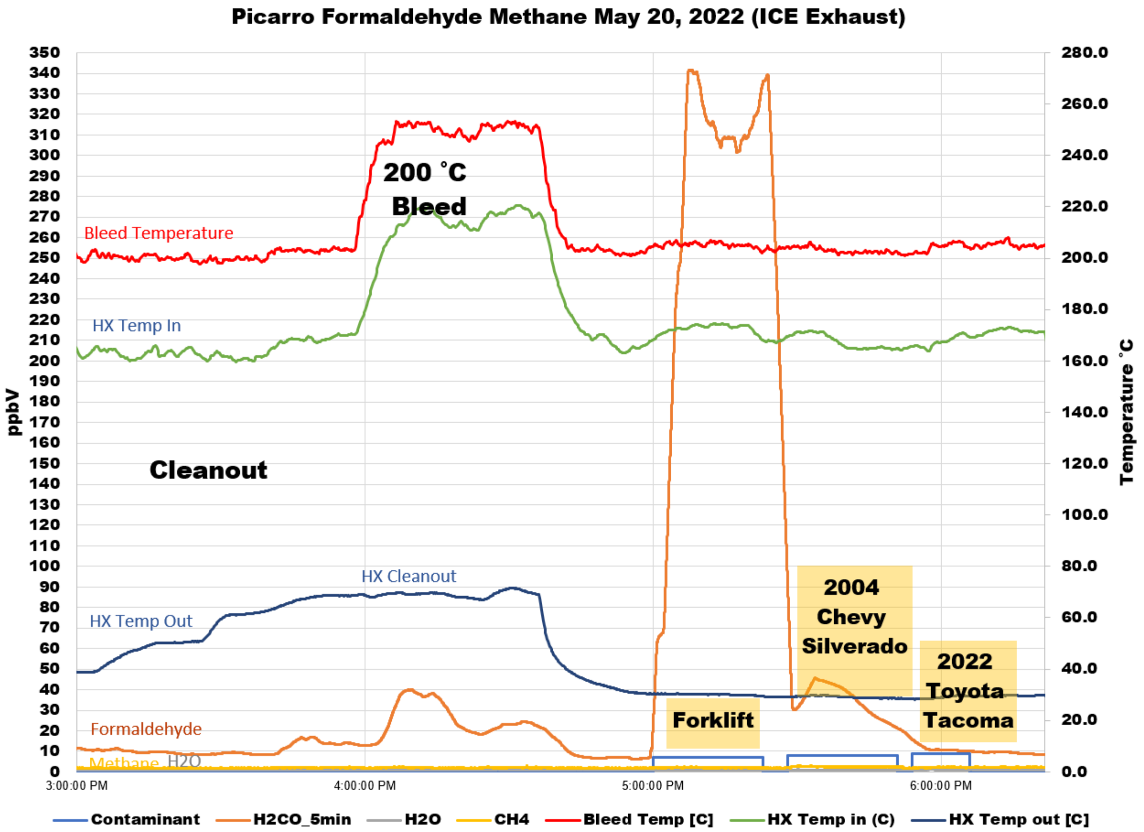


Figure 65. Picarro G2307 response to internal combustion engine exhaust

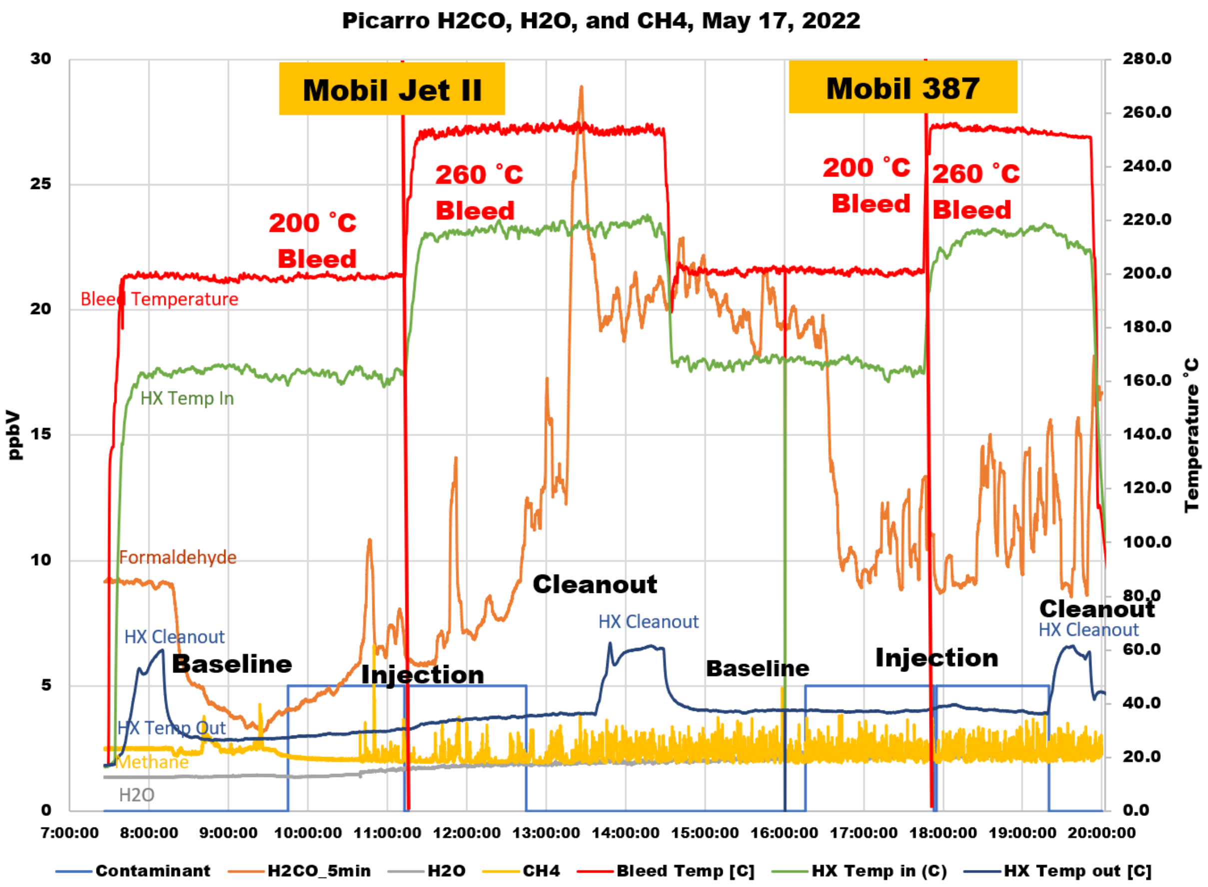


Figure 66. Increasing temperature of Mobil™ Jet™ II and Mobil 387 effect on formaldehyde level

Figure 67 indicates that elevating the temperature of 3000 psi hydraulic fluid (Eastman™ HyJet™ IV-A plus) and 5000 psi hydraulic fluid (Skydrol® PE-5) generated formaldehyde. The 5000psi hydraulic fluid increased to 3 ppbV at 200 ˚C, and increased to 12 ppb V at 250 ˚C. The level dropped to 6 ppbV during the heat exchange clean out cycle and fluctuated between 6 and 8 ppbV when HyJet™ IV-A plus was injected at 200 ˚C. Formaldehyde level was erratic at the 250 ˚C bleed condition, ranging from 13 to 25 ppbV. The level rapidly dropped to between 5-8 ppbV during the heat exchanger cleanout.

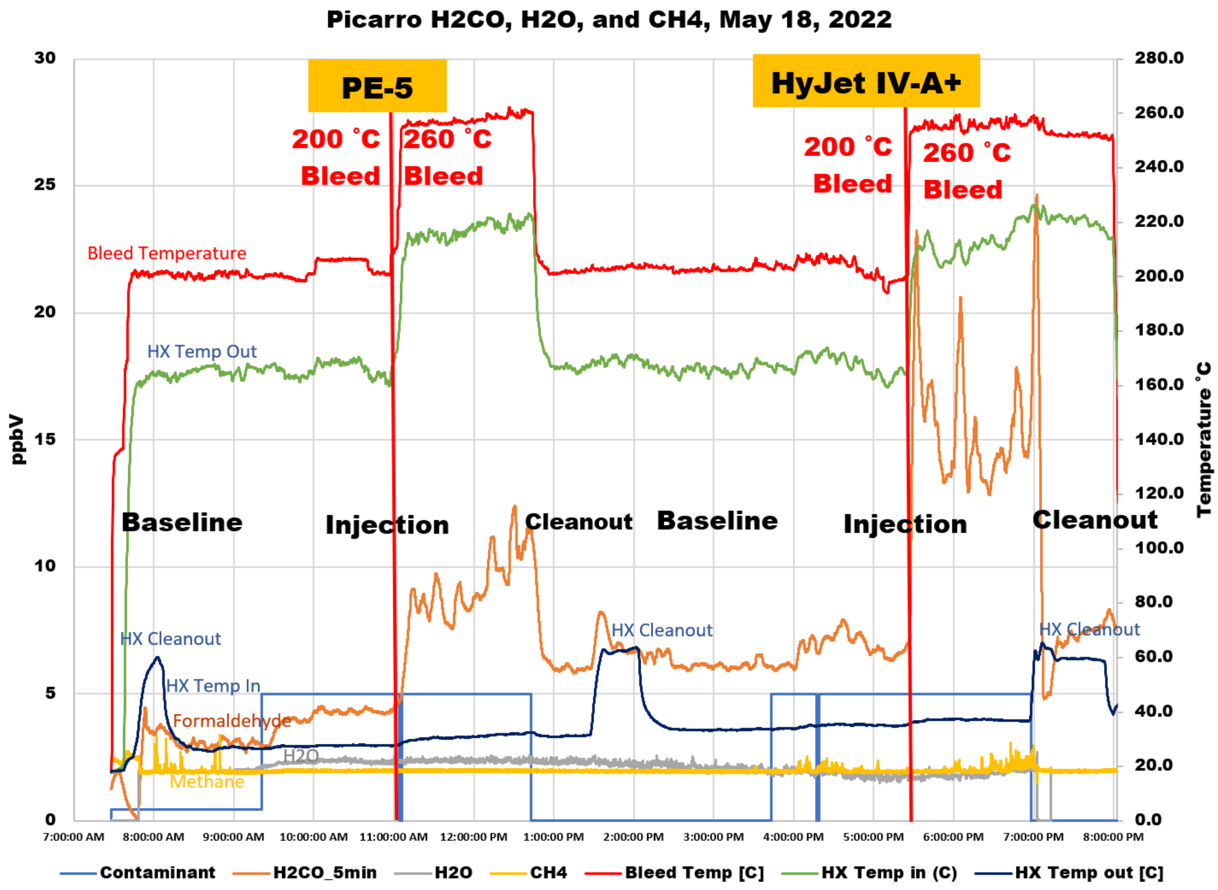


Figure 67. Formaldehyde generation from injection of hydraulic fluids

These finding from the CRDS formaldehyde analyzer indicate that very low levels of formaldehyde are evolved during heating of hydraulic fluid. The levels of formaldehyde evolved during heat exchanger cleaning were increased but were still at low parts per billion by volume (ppbV) levels which may be sufficient to create odor or irritancy. Abraham (2009) suggests the odor threshold to be around 1 ppbV in the supplementary data to their paper.

3.1.2.4 Comparative VOC / CO sensor observations

There were 10 PID sensors on the test benches: 1 Aerotracer®, 5 Honeywell ppbRAE 3000® PID, 1 Ametek MOCON II®, 2 Teledyne ACES®, and 1 TSI QTRAK XP® PID. Figure 68 indicates that two of the three ppbRAE sensors in the bleed air sample did detect deicing fluid when it was injected. Mobil™ Jet™ Oil II was injected following the deicing fluid, and the sensors did not respond to oil.

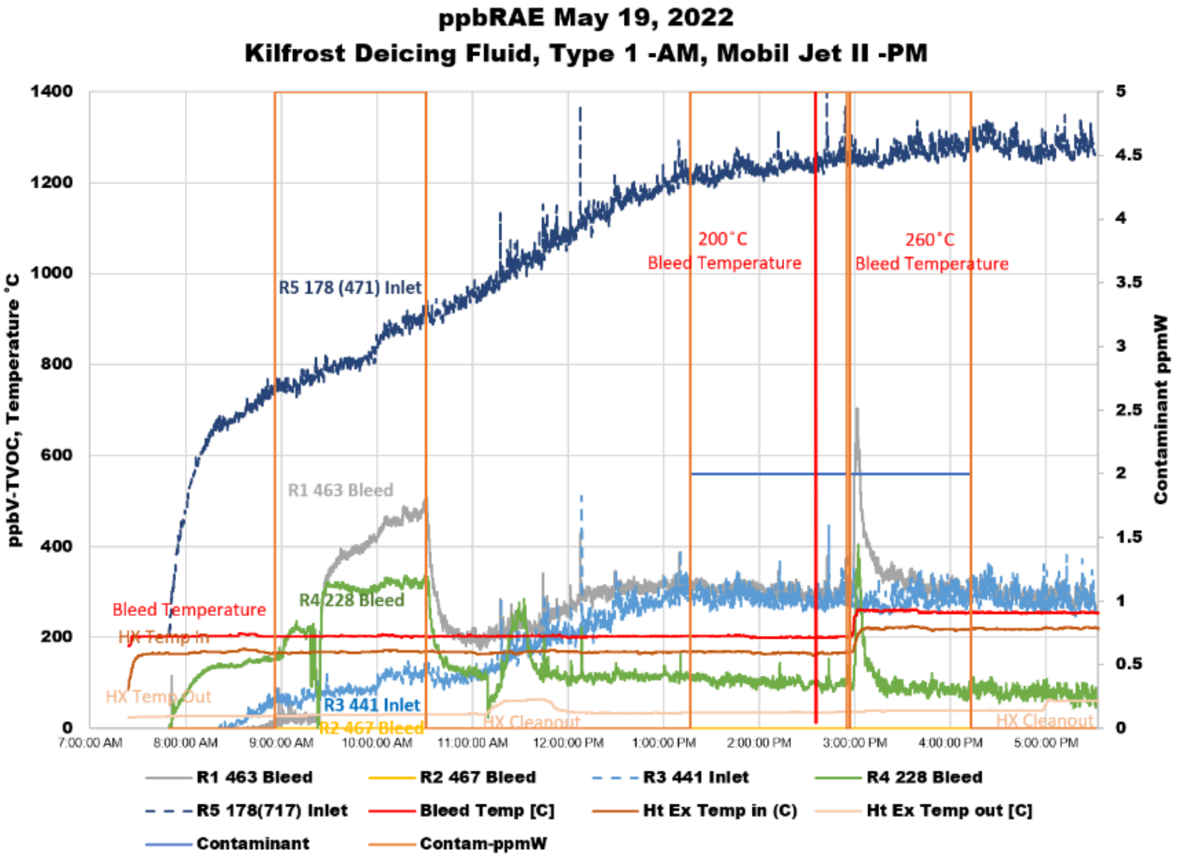


Figure 68. PID response to deicing fluid

Figure 69, which plots the response of three ppbRAE 3000® sensors to increasing concentrations of Mobil™ Jet™ Oil II, from 0 to 10 ppmW, indicate that the PID did not sense any change in oil injection rate. In addition, the sensor did not respond significantly during the heat exchanger exit temperature variation. The PID responded to contamination that was coming into the engine inlet, however. A fuel truck was delivering fuel near the inlet sample location.

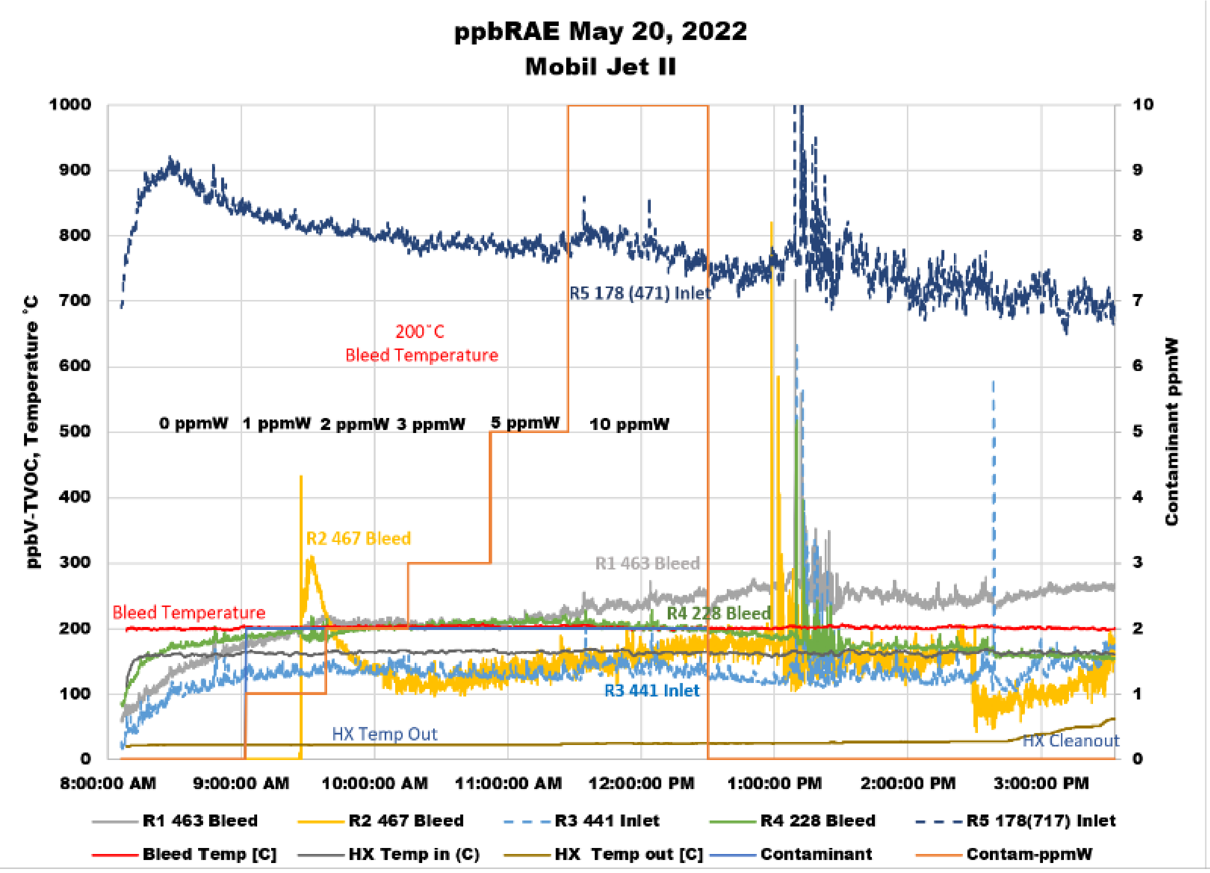


Figure 69. ppbRAE 3000 PID response to increasing concentrations of turbine oil

The response of the ppbRAE 3000® PID to hydraulic fluid is presented in Figure 70. The PID analyzers appeared to drift upward throughout the day, and there was no clear indication that they responded to deicing fluids. The PID does appear to be sensitive to internal combustion exhaust ingestion, as depicted in Figure 71.

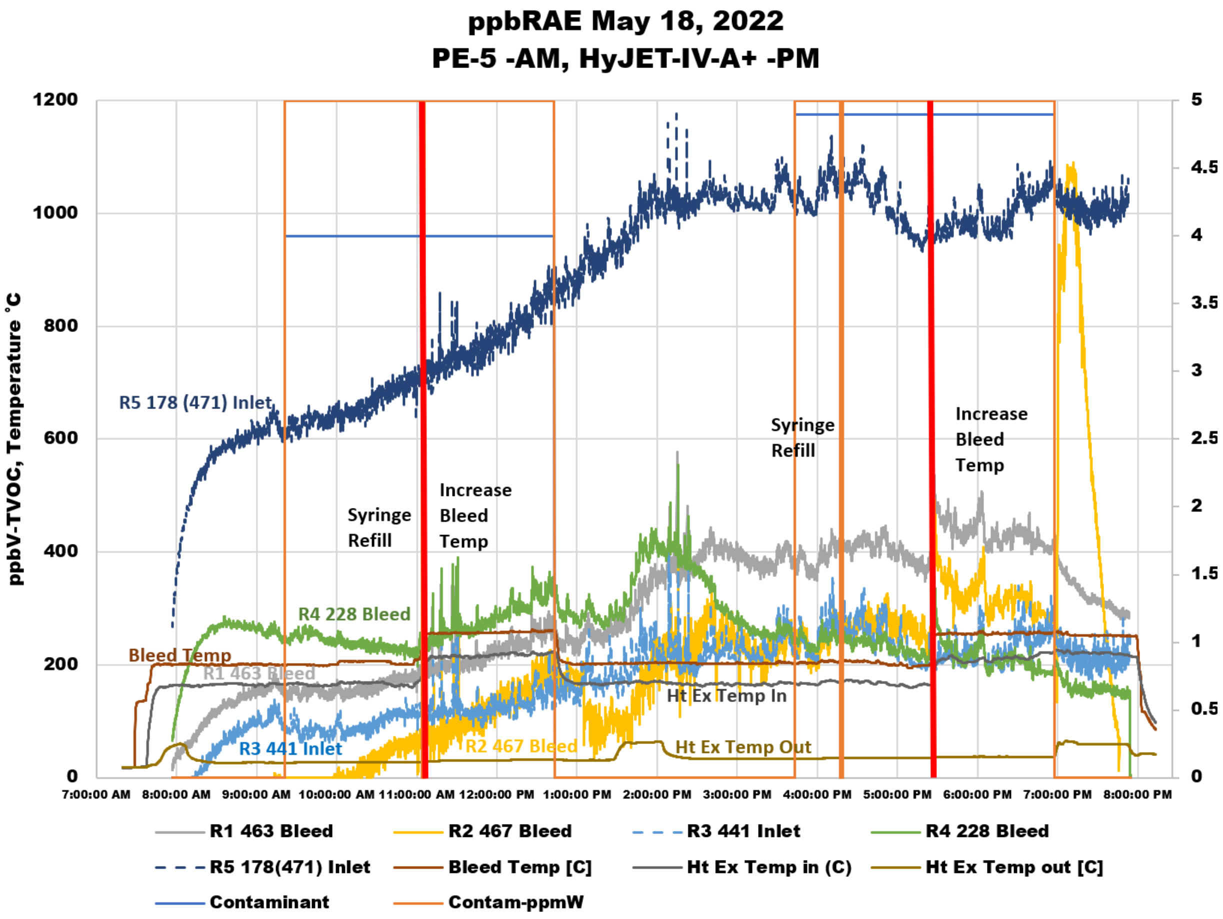


Figure 70. ppbRAE 3000® PID response to hydraulic fluid May 18, 2022

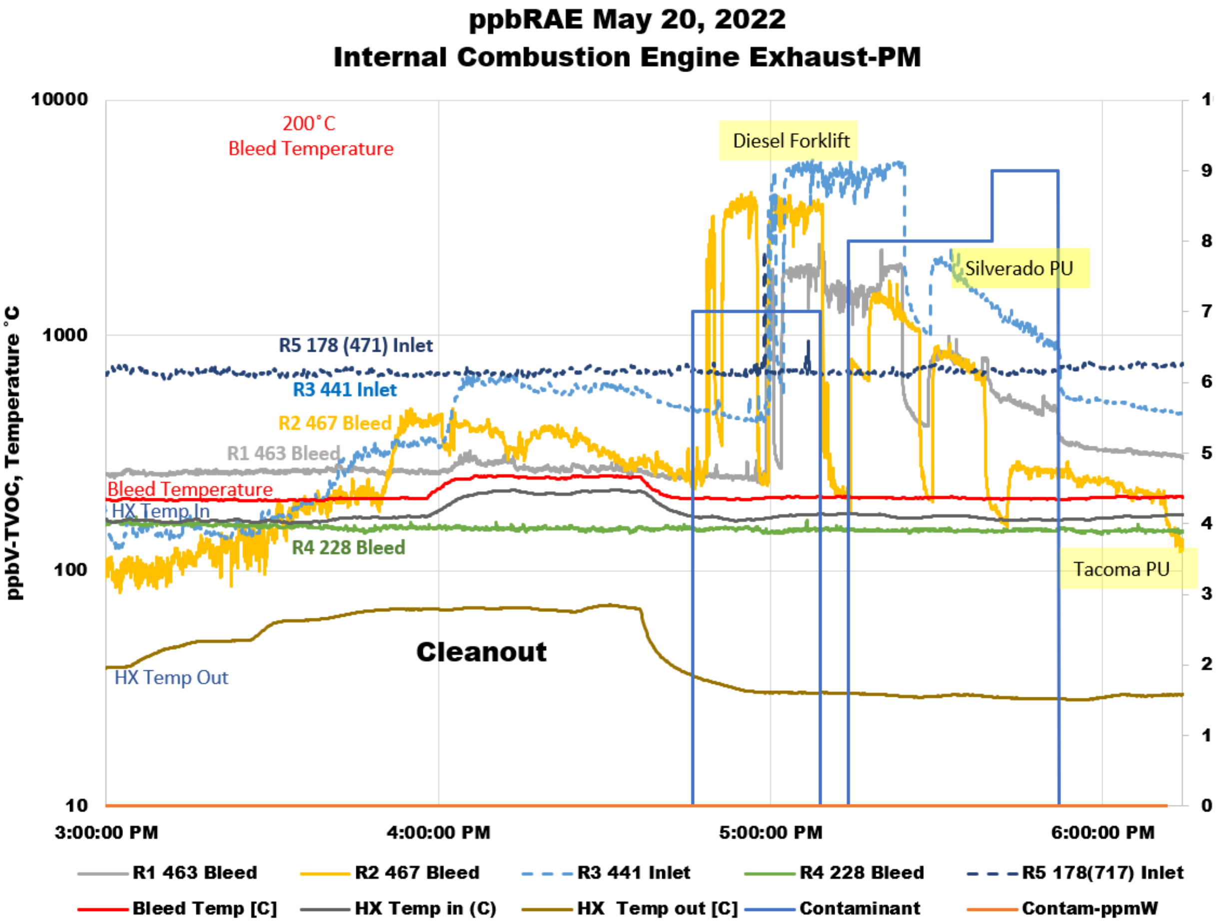


Figure 71. PID response to internal combustion engine exhaust

Figure 72 shows that carbon monoxide is not produced when bleed air temperatures are elevated to 260℃ (500℉) while Eastman™ 2389, a Mil-PRF-7808 oil is injected into the engine inlet.

The CO bleed appeared to increase in Figure 73 while injecting Mobil™ Jet™ II and increasing the temperature from 200℃ (392 ˚F) to 250℃ (482 ˚F). However, the response did not change when injection was discontinued, and the cleanout cycle began. This is more likely due to sensor drift than to the actual formation of CO. No change in the concentration between the cleanout baseline and injection of Mobil 387 in the afternoon was observed. This would lead to the conclusion that no CO is generated for Mil-PRF-2399 Standard and HTS oils between 200℃ (392 ˚F) and 250℃ (482 ˚F) bleed air temperatures.

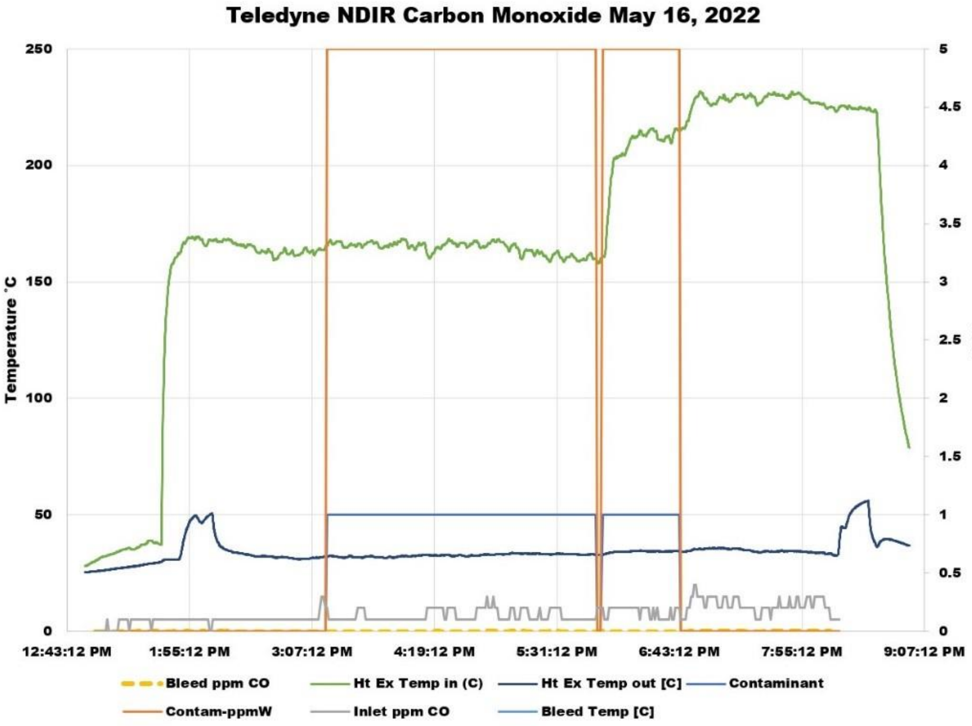


Figure 72. Teledyne 300e® NDIR CO response to increasing temperature of Eastman™ 2389

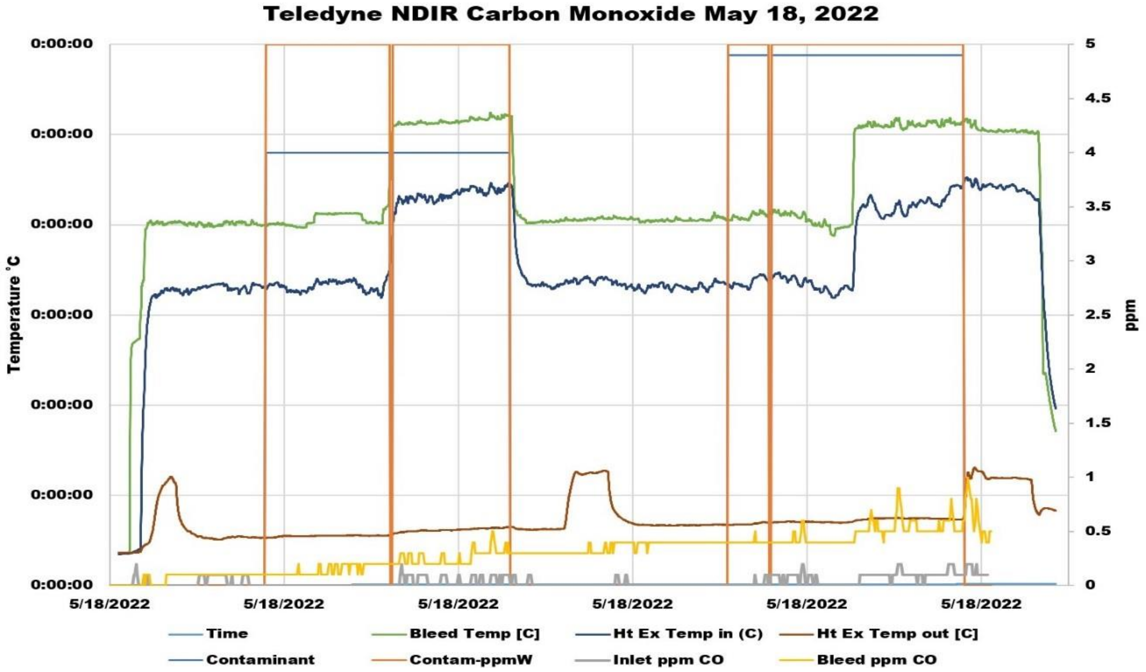


Figure 73. CO meter response to increasing temperature of Mobil™ Jet™ II and Mobil 387

A similar conclusion may be drawn for production of CO from Skydrol® PE-5 and HyJet™ IV-A plus (Figure 74). The inlet sample CO remained flat throughout the day, while the bleed sample drifted up to 0.5 ppmV. The cleanout cycle between fluid types did not reduce CO level.

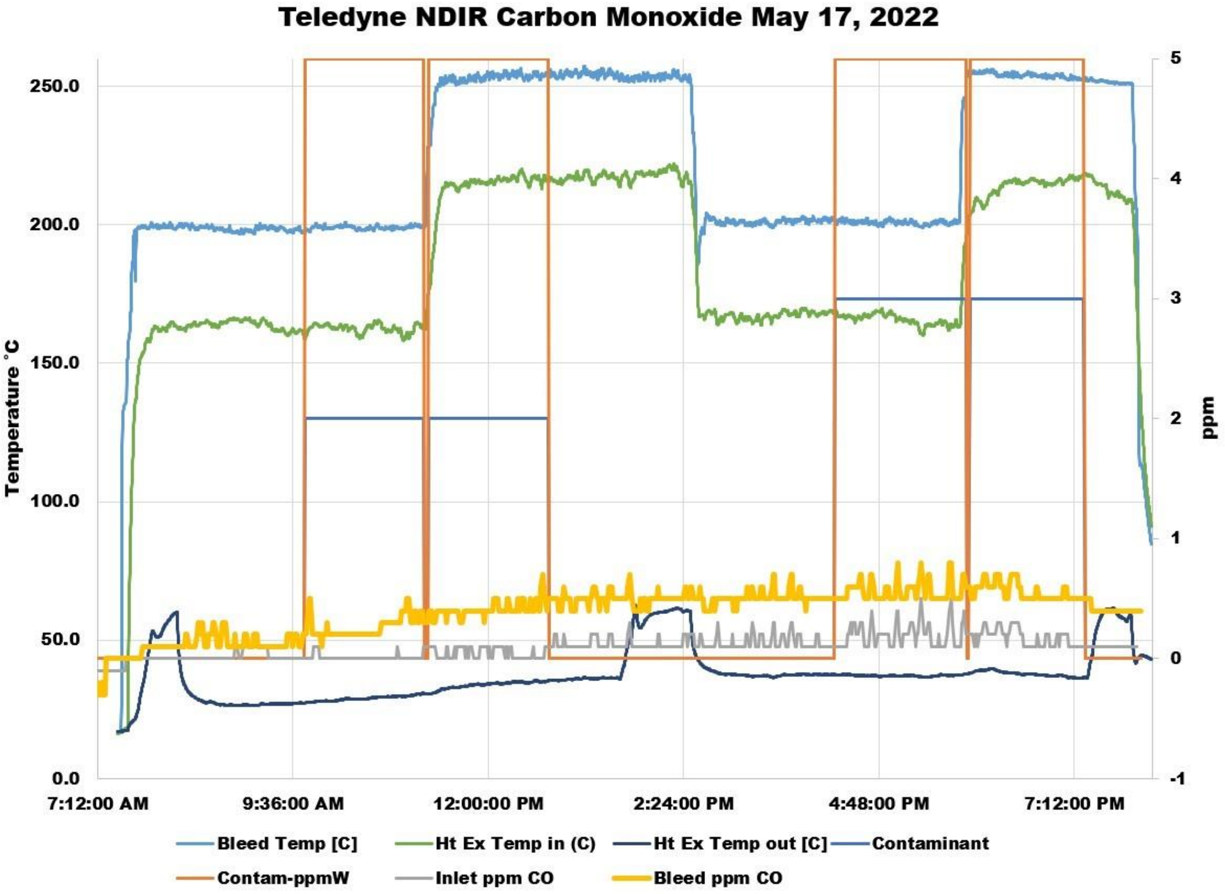


Figure 74. Teledyne 300e® NDIR CO response to increasing temperature of Skydrol® PE-5 and HyJet™ IV-A plus

Figure 75 indicates that CO was not generated during ingestion of deicing fluid at a bleed air temperature of 200℃ (392 ˚F), which is typical for APU bleed. The replicate of Mobil™ Jet™ II did seem to indicate an increase of around 0.2 ppm V, but this most likely was due to instrument drift since the level of CO did not diminish during the post-test cleanout cycle.

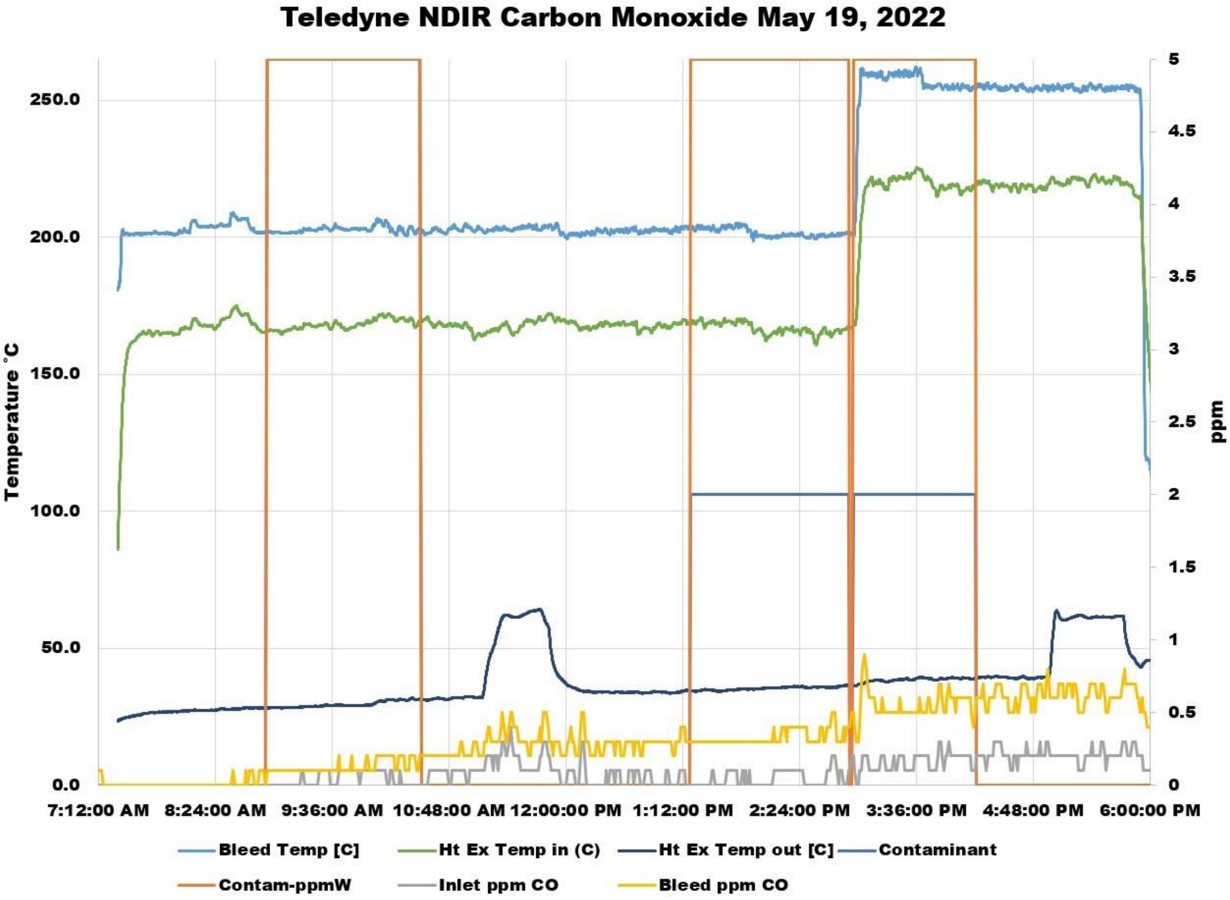


Figure 75. Teledyne 300e® NDIR CO response to increasing temperature of deicing fluid and Mobil™ Jet™ II replicate sample

Figure 76 indicates that CO is not produced as the level of Mobil™ Jet™ Oil II is increased from 0 to 10 ppmW at an engine bleed of 200℃. Figure 76 also shows that when CO is present, like the case for the diesel forklift and for the 2004 Chevy Silverado tested with a cold catalytic converter, the CO is readily measurable.

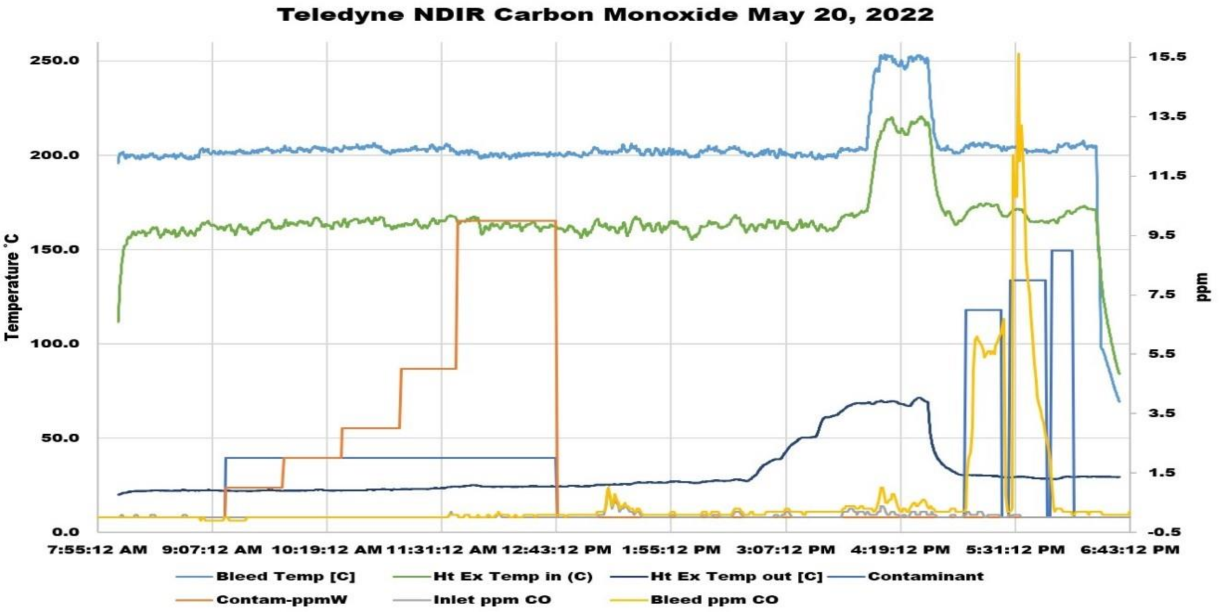


Figure 76. Teledyne 300e CO response to increasing concentrations of turbine oil

Figure 77 provides the Teledyne ACES® VOC and CO sensor response to increasing levels of Mobil™ Jet™ II. No response is observed on the CO sensors at the 5 ppbW and 10 ppbW ingestion conditions, but the VOC sensor appears to track the increasing concentrations of oil injection.

Figure 78 shows QTRAK XP® CO, VOC, formaldehyde, ozone, and ozone sensor response when injecting increasing concentrations of Mobil™ Jet™ II into the engine inlet, and when sampling exhaust from the test vehicles. The electrochemical CO sensor appeared to have a slight response. The signal from the formaldehyde sensor appeared to be near the minimum level of detectability. None of the other gas sensors appeared to respond to the oil injection. There appeared to be external contaminant ingestion following the test, as the NO and CO sensors both responded. The VOC, Ozone, NO, formaldehyde, and CO sensors responded to diesel exhaust from the forklift. This provides some evidence that electrochemical sensors, such as ozone, were responding to contaminants other than those which they were calibrated for. Electrochemical sensors, in order to respond accurately to oil and hydraulic fluid contamination, would need to be calibrated with a gas mixture that contains all the gaseous contaminants. A single contaminant blended in nitrogen or air is not sufficient for calibration of electrochemical sensors used for sensing bleed air contaminants, per personal discussions with Sensirion and Interscan.

The Teledyne ACES® CO sensors in Figure 79 appear to respond to both Mobil™ Jet™ II and to Mobil 387 at the start of contaminant ingestion. The effect of the temperature increase appears to be lesser than the increase in concentration. The two instruments had different levels of response to the same source.

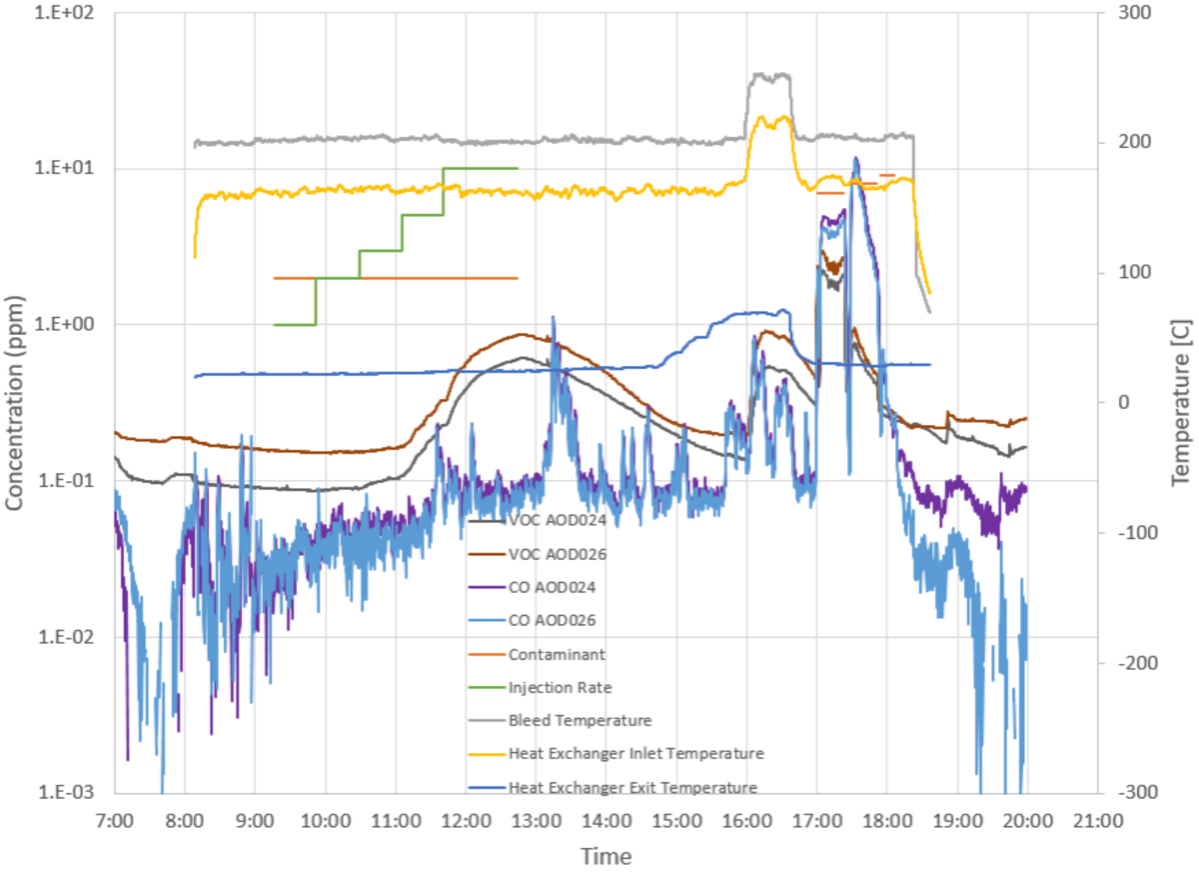


Figure 77. Teledyne ACES VOC/CO response to increasing concentrations of Mobil™ Jet™ II May 20, 2022

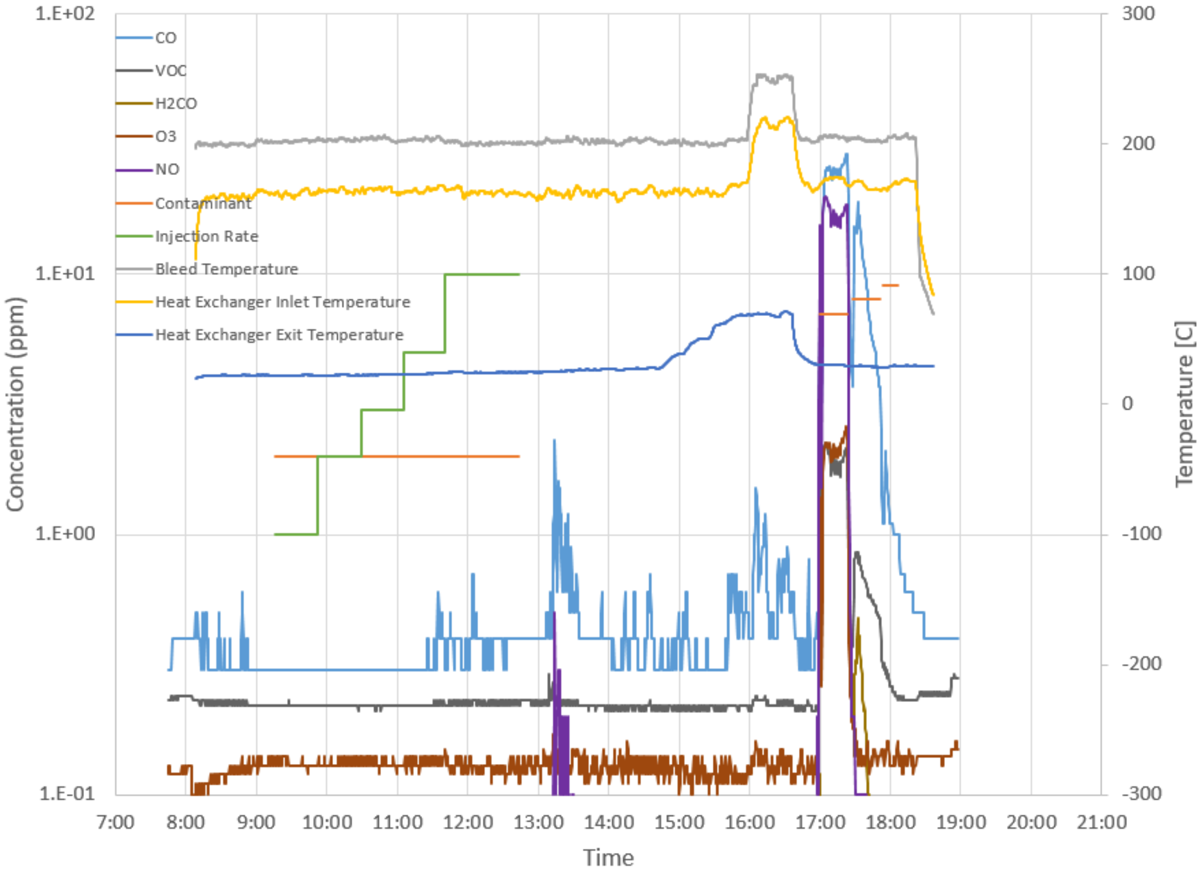


Figure 78. QTRAK XP® response to increasing concentrations of Mobil™ Jet™ II May 20, 2022

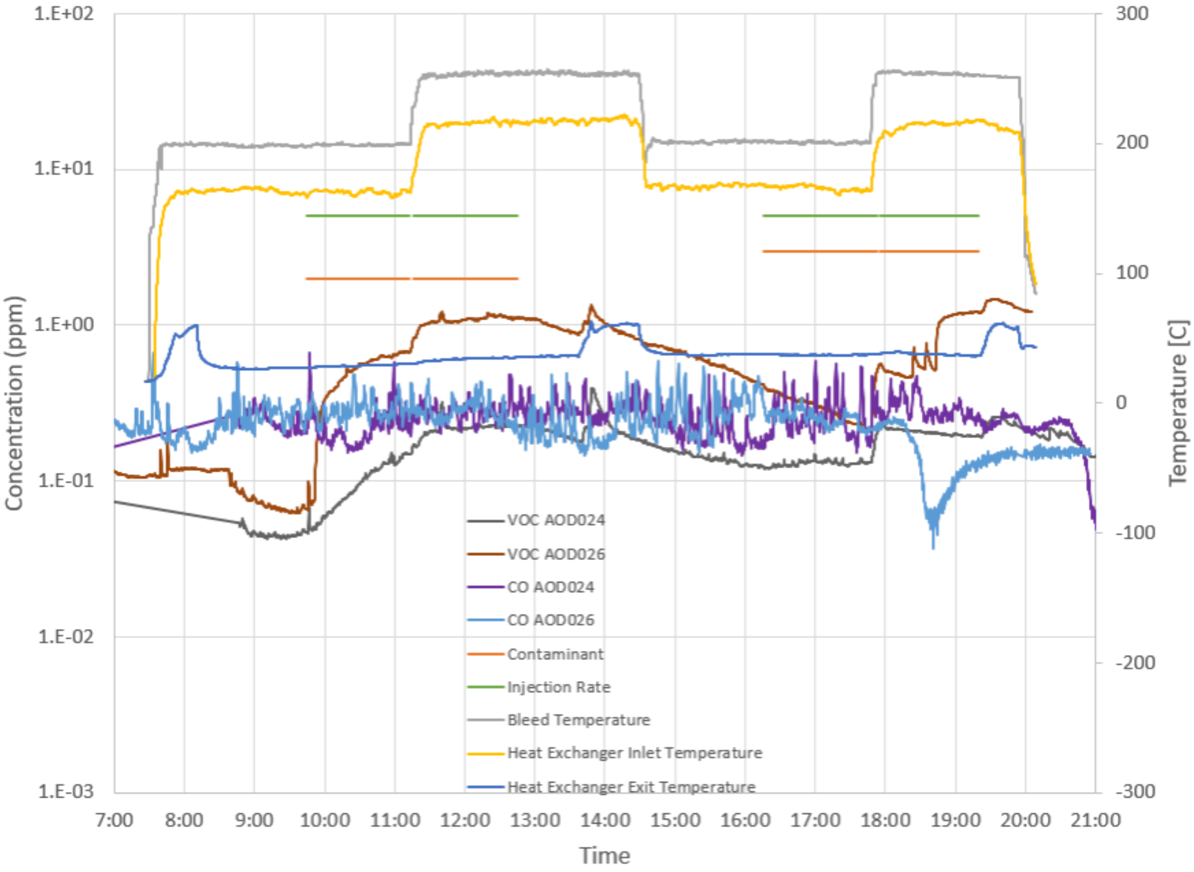


Figure 79. Teledyne ACES® PID and CO response Mobil™ Jet™ II and Mobil 387 May 17, 2022

The VOC and CO sensors do not seem to be sensitive to Skydrol® PE-5 in Figure 80. Both sensor package VOC sensors respond to the contaminants coming off the heat exchanger during the PE-5 cleanout cycle. The HyJet™ IV-A plus contaminant did not seem to drive an ACES sensor response at 200 ˚C. The sensors did show a response as soon as the bleed temperature was increased. The concentration dropped as soon as the injection concluded, but again increased when the pack temperature was elevated in the HyJet™ IV-A plus cleanout cycle.

3.1.2.5 Aerotracer observations

The Aerotracer contains eight sensor channels. The response of the Aerotracer to the various contaminants is presented by the contaminant challenge type. These charts do not fully capture the Aerotracer capability, as it also has a compound identification library to enable the user to identify contaminant type. The eight Aerotracer sensor channels are plotted in the following charts to illustrate Aerotracer response to the test contaminants.

The Ion Mobility Scanner (IMS) channels of the Aerotracer (C-D and A-B) and Channel H -PID appear to be the responsive channels for detection of Eastman™ 2389 (Figure 81). Sensor F-MOS also responded, but sensor resistance is inversely proportional to concentration.

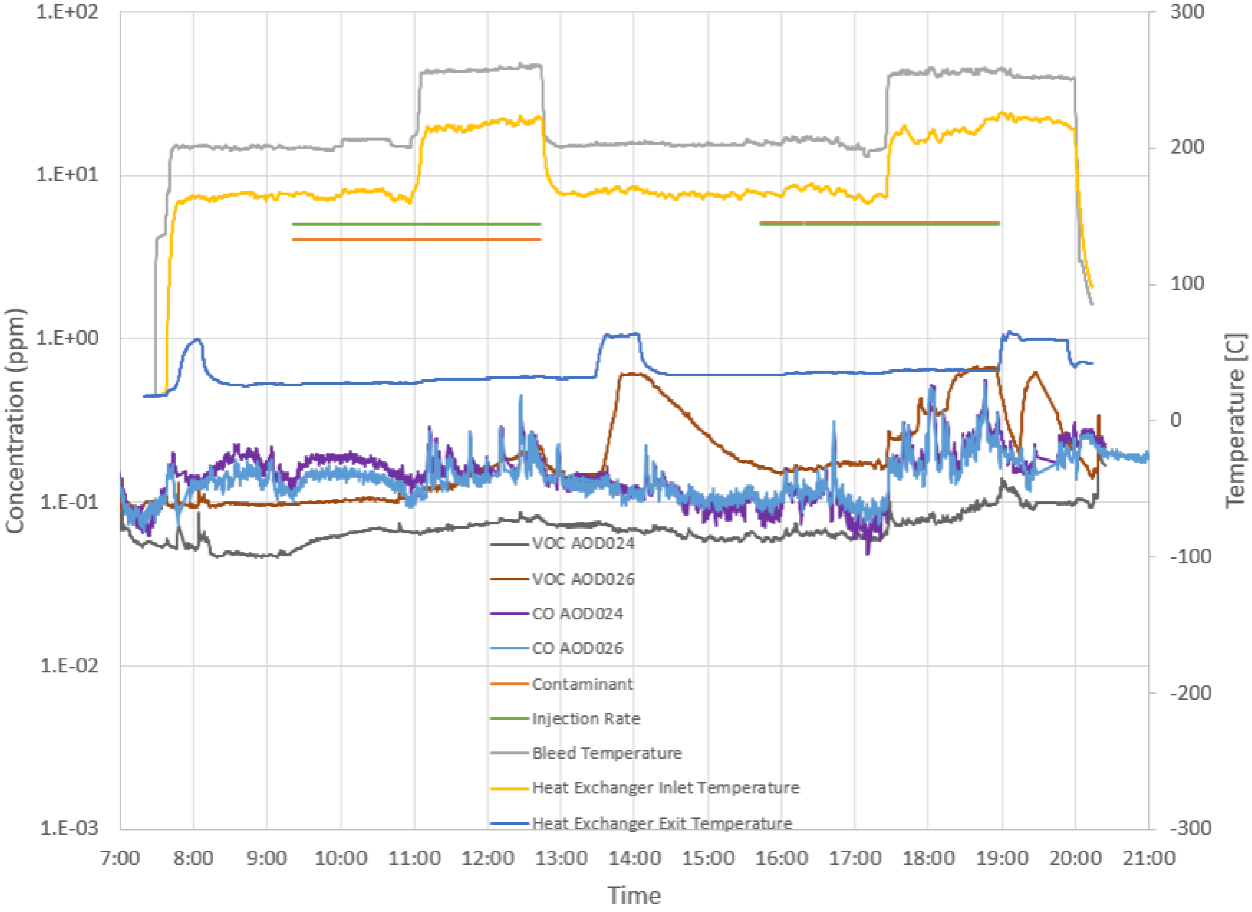


Figure 80. Teledyne ACES PID/CO response to Skydrol® PE-5 and HyJet™ IV-A plus May 18, 2022

Figure 82 is plotted on the same scale as Figure 81. The H-PID sensor appears responsive to the turbine oils compared to the responsiveness to the lighter Mil-PRF-7808 oil. The IMS also appeared less responsive to the heavier Mil-PRF-23699 oils. Sensor F-MOS did respond inversely to concentration for oil.

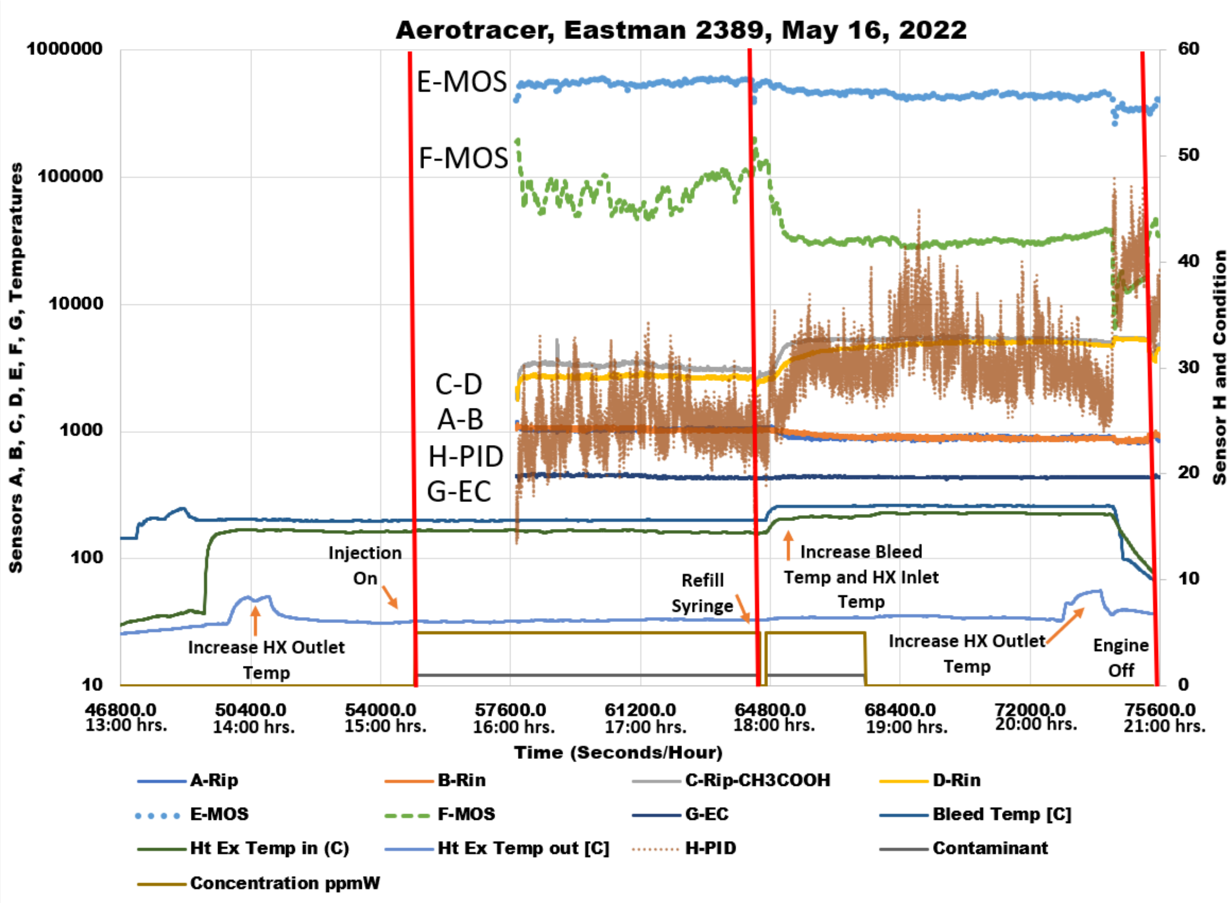


Figure 81. Aerotracer response to Eastman™ 2397

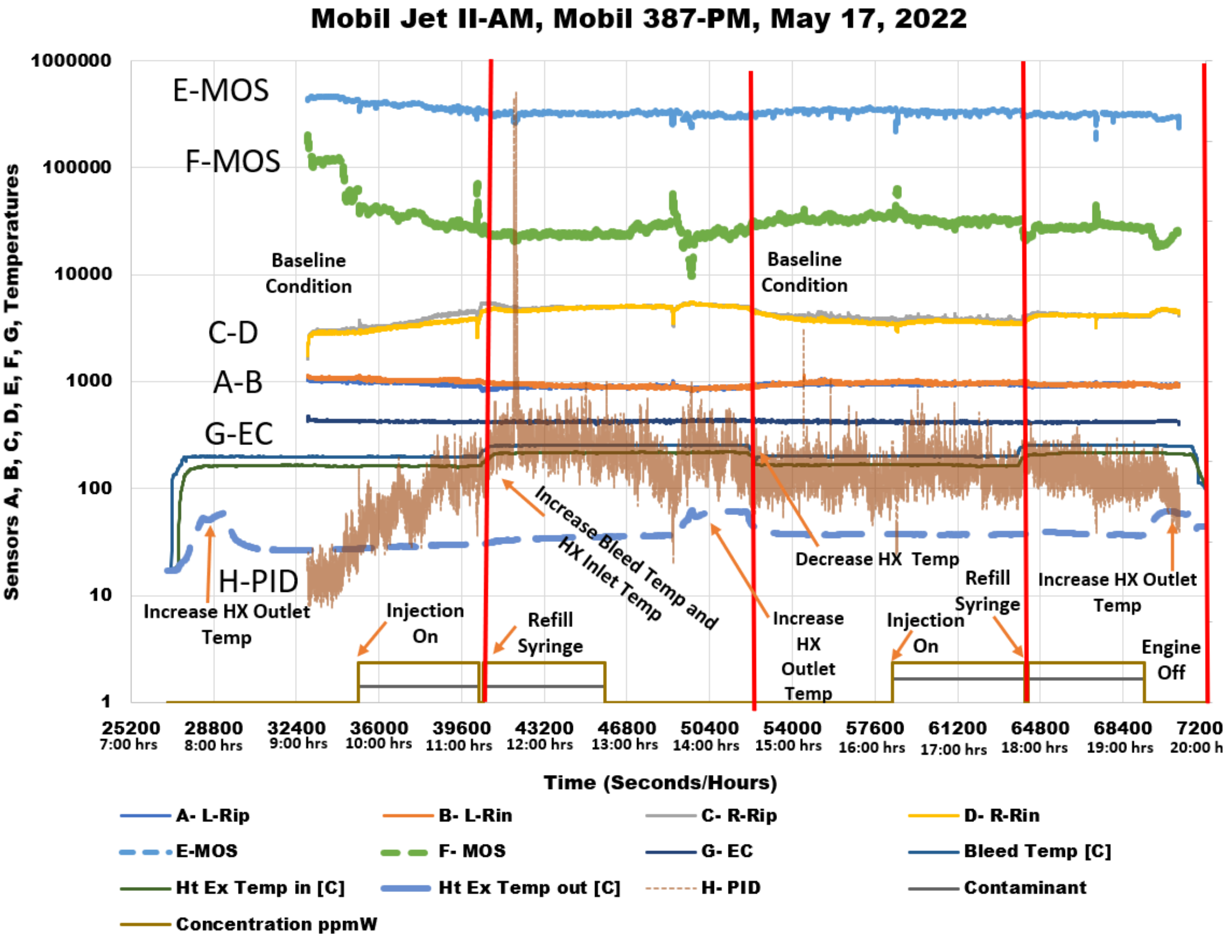


Figure 82. Aerotracer response to Mobil™ Jet™ II and Mobil 387

The Aerotracer® was turned to cleaning mode between the hydraulic fluid test conditions so the effect of warming the heat exchangers after injecting hydraulic fluid, and the response of sensor F-MOS could not be determined (Figure 83).

The sensors were only turned on momentarily during deicing fluid ingestion, as deicing fluid tends to contaminate the internal Aerotracer tubing and requires an overnight cleaning cycle to restore operation (Figure 84). The sample identification feature is commonly used when utilizing the Aerotracer, and it is not necessary to continuously sample for the Aerotracer to perform compound identification and obtain ion mobility spectra.

Sensor channels C-D, F-MOS, and G-PID responded to increasing concentrations of Mobil™ Jet™ II at the 200 ˚C bleed air injection condition (Figure 85).

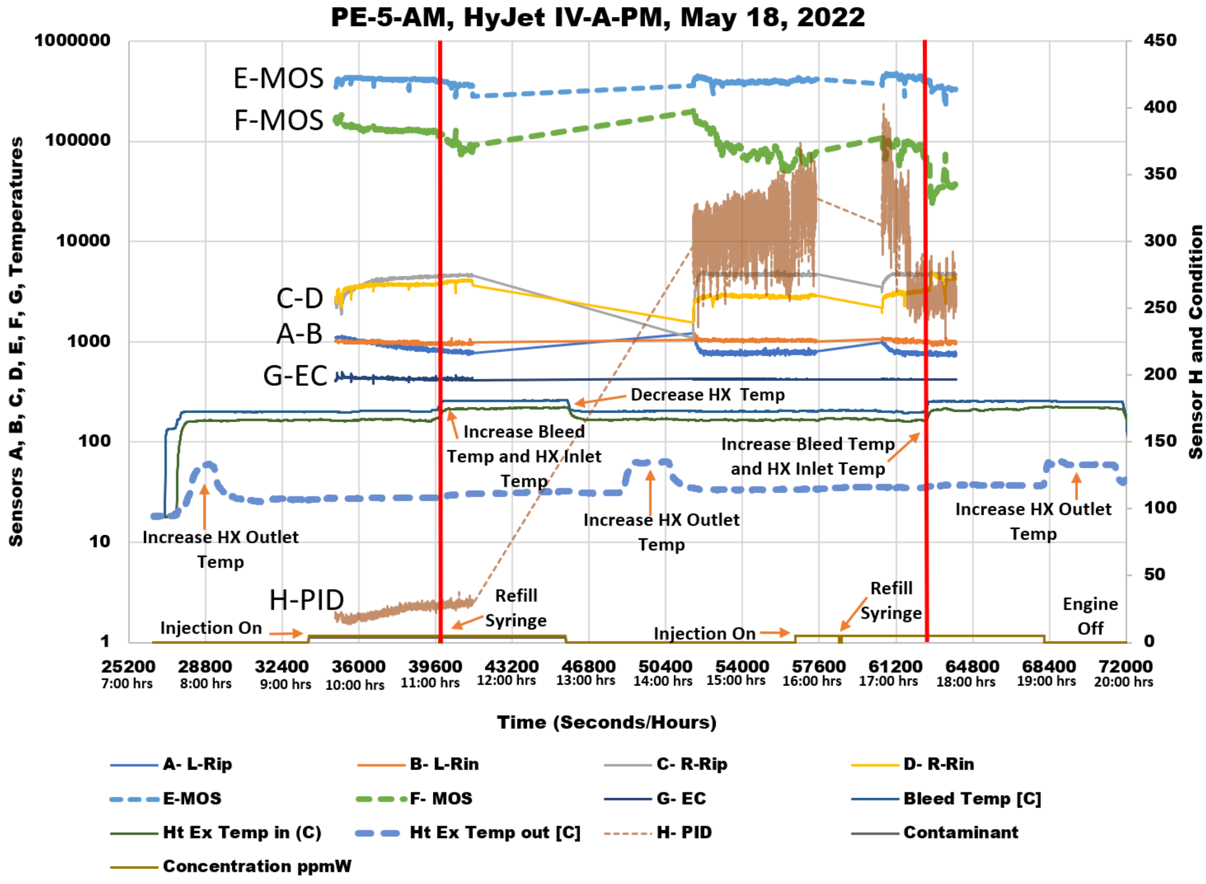


Figure 83. Aerotracer response to hydraulic fluid

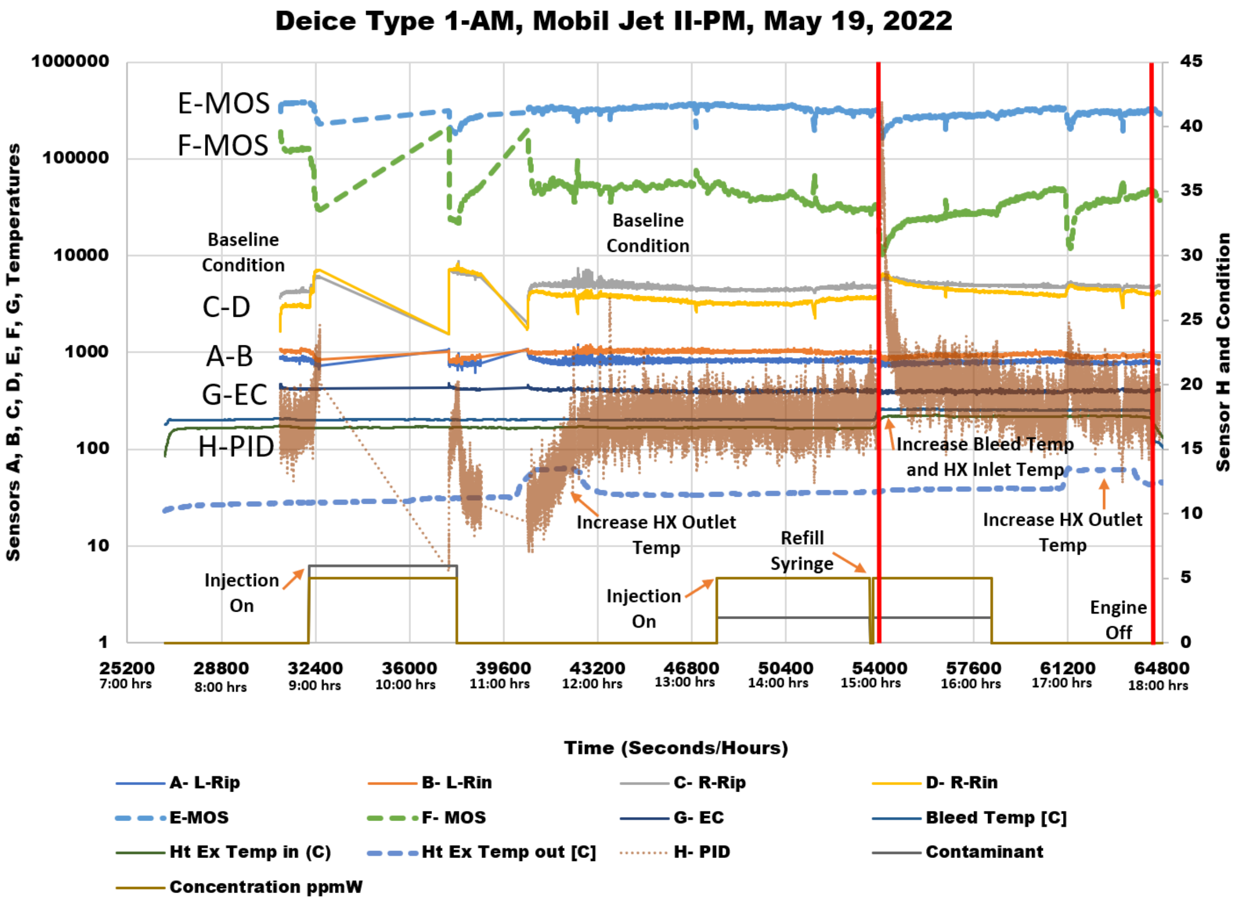


Figure 84. Aerotracer response to deicing fluid

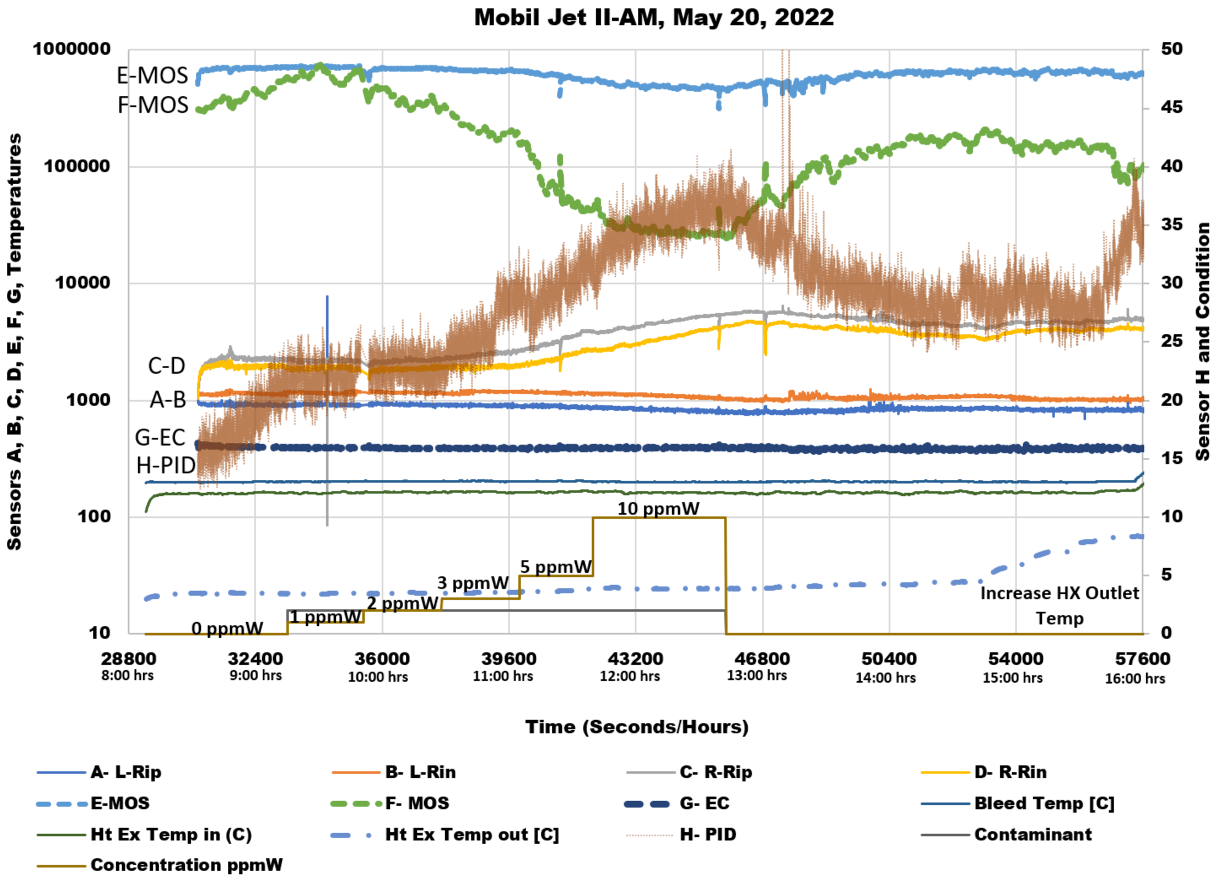


Figure 85. Aerotracer response to increasing concentrations of Mobil™ Jet™ II

Figure 86 shows that the Aerotracer was extremely sensitive to the vehicle exhaust that was ingested from the diesel forklift and from the 2004 Chevy Silverado. The E-MOS responded to exhaust from the 2022 Toyota Tacoma. The E-MOS did not appear to be responsive to the ingested contaminants in other tests.

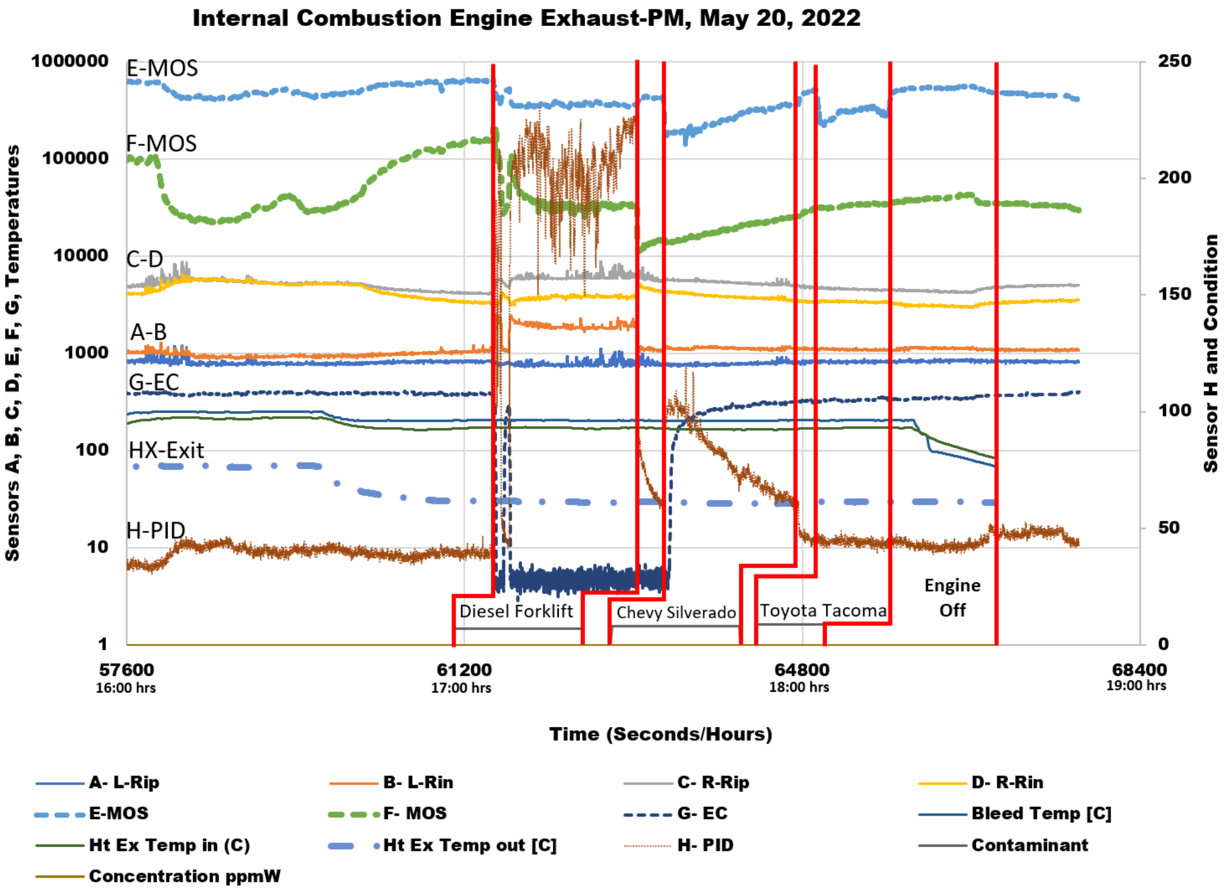


Figure 86. Aerotracer® response to ingestion of vehicle exhaust

3.1.2.6 *Pall cabin air quality sensor observations*

The Pall Cabin Air Quality Sensor uses a form of pattern recognition between its sensor to recognize and identify an air contamination event. Pall uses yellow, purple, and green bars in its charts to represent detection of turbine oil, hydraulic fluid, and deicing fluid, respectively.

Figure 88 is an example of identification of hydraulic fluid while the contaminant was injected into the engine. The system recognized Skydrol® PE-5 and HyJet™ IV-A-plus as hydraulic fluids, as depicted by the purple bars in Figure 87.

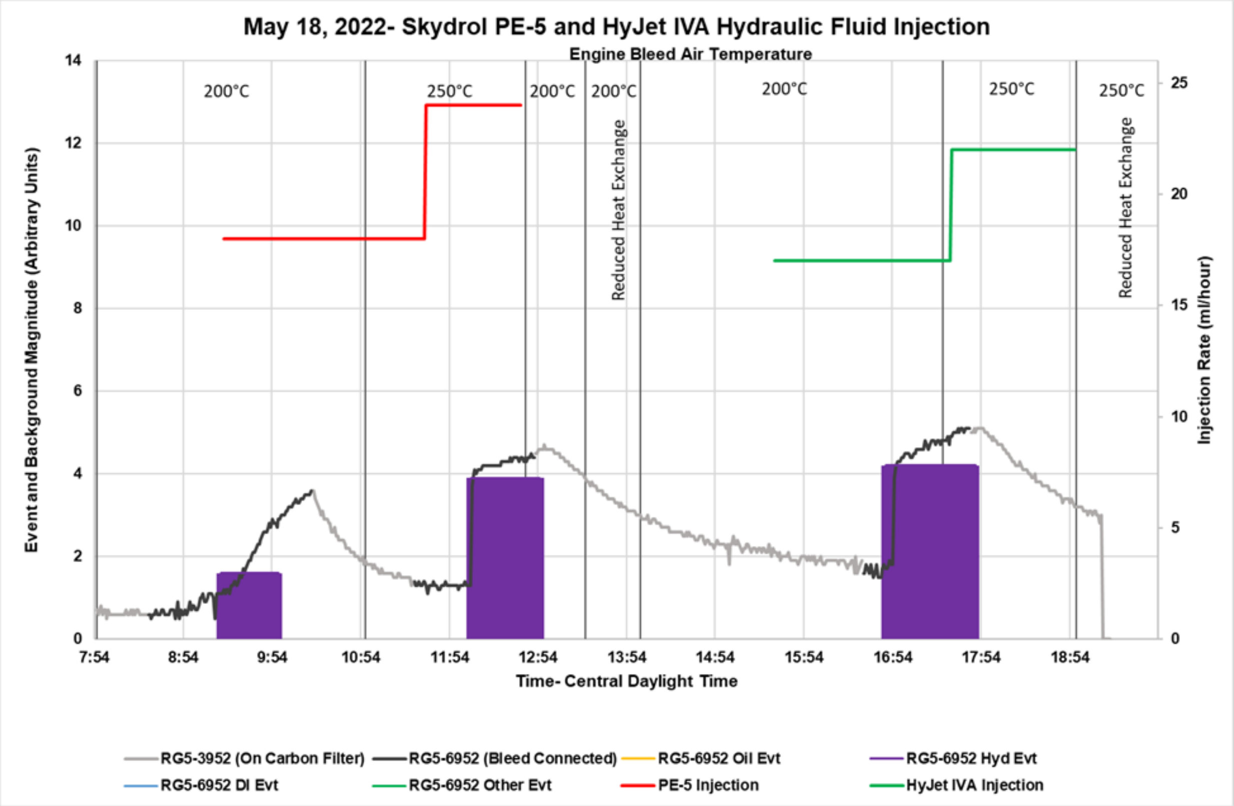


Figure 87. Pall CAQS response to hydraulic fluid

The sensor also properly recognized system contamination with hydraulic fluid while deicing fluid was being injected (Figure 88). This observation was supported as being correct by the Aerotracer also identifying the presence of hydraulic fluid, and by the laboratory analyses taken during the deicing fluid injection.

Figure 89 illustrates the Pall CAQS response to contamination events through the use of gold bars. The CAQS required cleanup time between tests to avoid contamination from the quantities of contaminant ingested during the testing, so system cleanup times were used as times to purge the CAQS in preparation for the following contamination events.

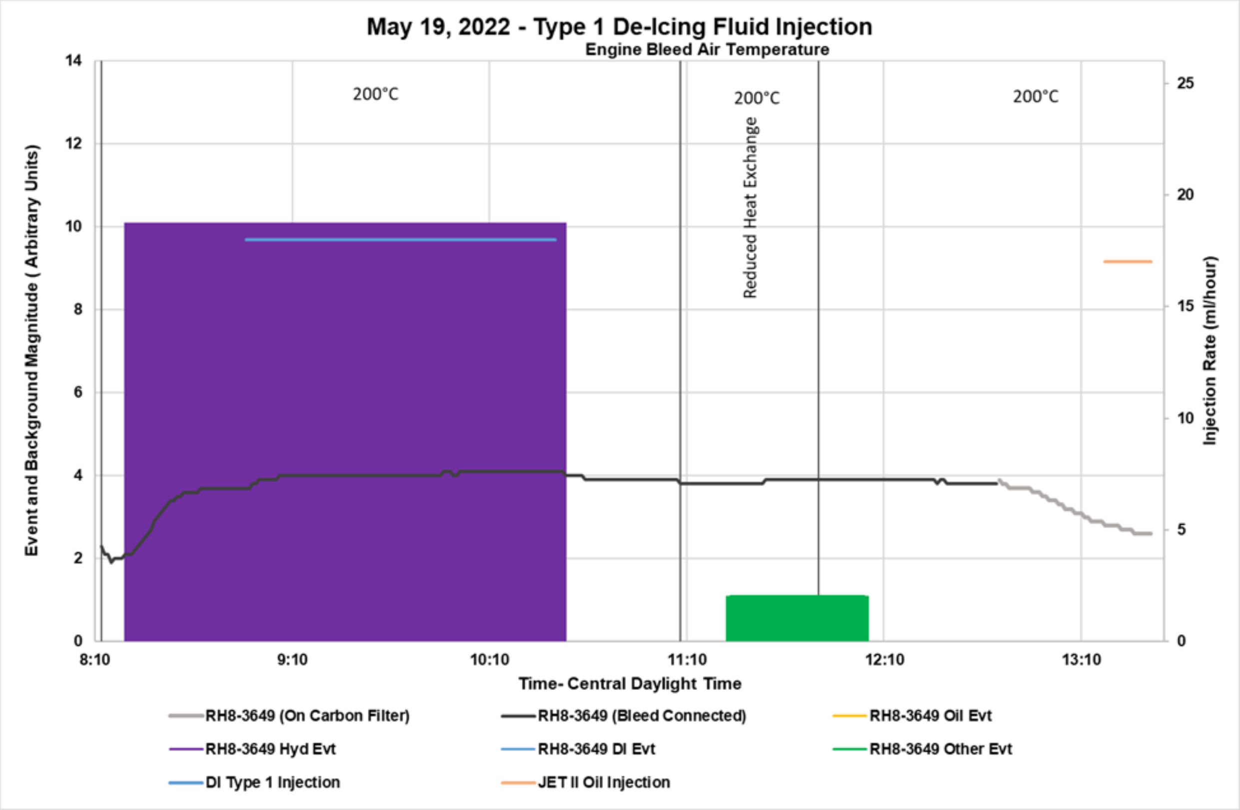


Figure 88. Pall CAQS detection of hydraulic fluid contamination during deicing fluid injection

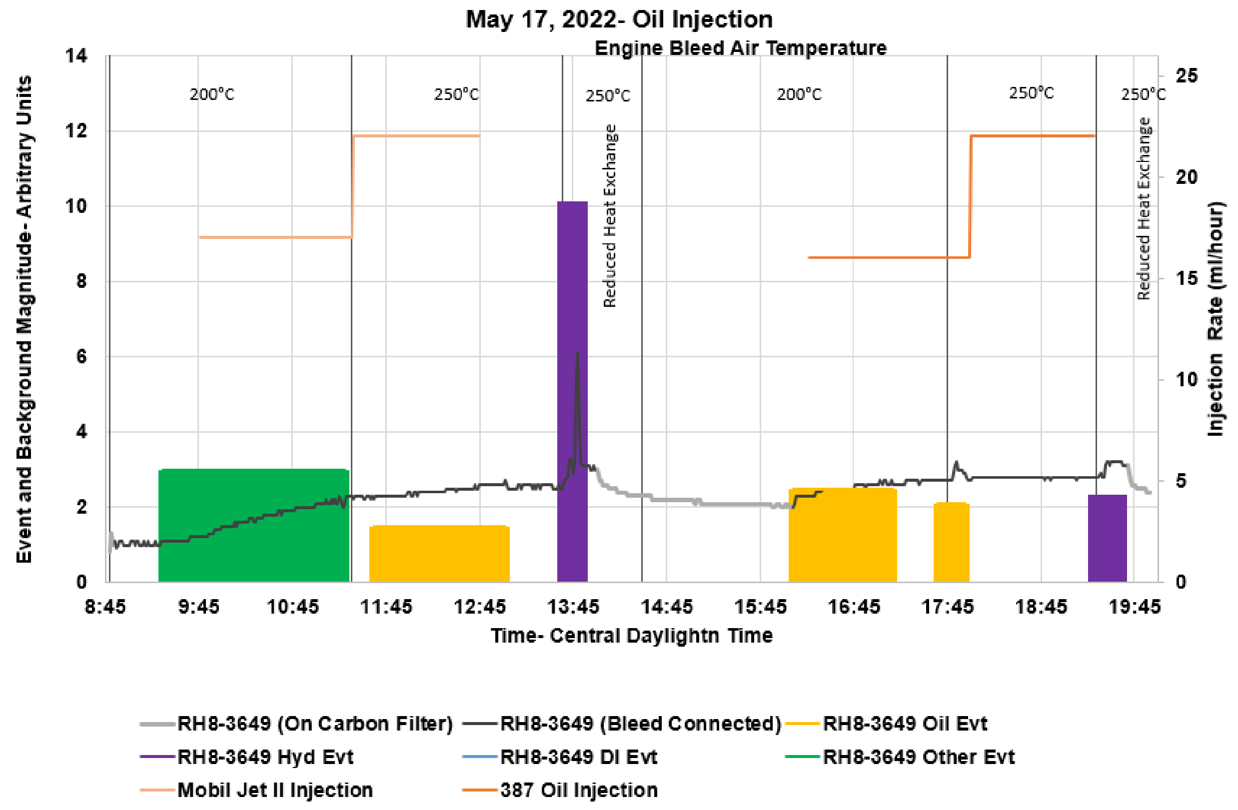


Figure 89. Pall CAQS response to turbine oils

3.1.2.7 Griffin G510 results

The Griffin G510 report for May 16-20 is found in Appendix H- Griffin G510 Lab Report. The most common compound was hexane, identified in 14 of 17 samples, and all but one bleed sample at levels above 5 ppbV. Three inlet samples and one bleed sample showed 1,1-Difluoroethan was present. The Eastman™ 2389 inlet samples at 260 ˚C bleed temperature contained the highest levels of hexane and 1,1-Difluoroethane. Three samples detected 2-Propanol, with the greatest concentration being in the cleanout bleed sample at the end of the testing on May 20th. The May 17th inlet sample of Mobil™ Jet™ II at 200 ˚C bleed showed that 1-butanol was detected. One likely source for this could be contamination from the SMPS, which utilizes butanol to initiate particle condensation. Isobutane was present in Mobil™ Jet™ II bleed at 250 ˚C, and the Mobil 387 baseline bleed sample on May 17th. The analyst summarized that any remaining compounds would likely be less than five ppbV in concentration.

3.2 Laboratory chemical sample results

Laboratory chemical sample result summaries are presented in the body of this report. Visit the accompanying dataset (KSU, 2024) information to obtain the full data set information, quality control information, and chromatograms. A listing of the data sets found in the database (KSU, 2024) and a chronological revision history is summarized to help the reader follow the various reports (Table 14).

Table 14. Summary of data sets in the FAA database for ground test data

Database		
Report Number	**Method**	**Report Date**
Atmospheric Analysis & Consulting, Inc. Report Number 221141	EPA TO-11A DNPH Cartridges	June 6, 2022
221141-EPA TO-11-EDD	EPA TO-11A DNPH Cartridges	June 6, 2022
RJ Lee report number 205178, Revision 1	EPA 8270E Quartz Filters	November 16, 2023
W205178 Rev 1 EDD	EPA 8270E Quartz Filters	November 28, 2023
RJ Lee report number 205131, Revision 1, dated	EPA TO-13A PUF XAD	November 23, 2023
W205131 EDD Rev 1	EPA TO-13A PUF XAD	November 23, 2023
RJ Lee report number 205177, Revision 1	EPA TO-13 PUF/XAD	November 16, 2023
W205177 EDD Rev 1	EPA TO-13 PUF/XAD	November 28, 2023
Atmospheric Analysis & Consulting, Inc. Report Number 221095	EPA TO-15 Summa Canisters	May 26, 2022
221095-TO15-EDD	EPA TO-15 Summa Canisters	October 13, 2023
Atmospheric Analysis & Consulting, Inc. Report Number 221106	EPA TO-15 Summa Canisters	May 31, 2022
221106 TO15-EDD	EPA TO-15 Summa Canisters	October 13, 2023
Atmospheric Analysis & Consulting, Inc. Report Number 221134 Rev 1	EPA TO-15 Summa Canisters	May 27, 2022
221134-TO15-EDD	EPA TO-15 Summa Canisters	October 13, 2023

Database		
Report Number	**Method**	**Report Date**
RJ Lee Report Number W205179, Revision 1	EPA TO-17 Thermal Desorption Cartridges	January 29, 2024
RJ Lee Report Number W205179 Chromatograms	EPA TO-17 Thermal Desorption Cartridges	August 30, 2022
W205179 Rev 1 EDD	EPA TO-17 Thermal Desorption Cartridges	March 4, 2024

3.2.1 EPA TO-11A (aldehydes and ketones)

Forty-two DNPH impregnated silica gel samples were sent to Atmospheric Analysis and Consulting , Inc. (AAC) for analysis by EPA Method TO-11A (U.S. Environmental Protection Agency, 1999). Applicable compounds that the EPA lists in the method include formaldehyde, acetaldehyde, o-tolualdehyde, acetone, isovaleraldehyde, valeraldehyde, butyraldehyde, m-tolualdehyde, propionaldehyde, crotonaldehyde, 2,5-dimethylbenzaldehyde, benzaldehyde, p-tolualdehyde, hexanaldehyde, and methyl ethyl ketone. TO-11A test results in their entirety are included in the Atmospheric Analysis & Consulting, Inc. Report Number 221141, dated June 6, 2022 found in the accompanying dataset (KSU, 2024). The analysis and minimum sample reporting limits for the 64 30-liter samples are listed in Table 15. Calibration spike recoveries ranged from approximately 97% to 105%.

Table 15. TO-11A minimum sample reporting limits (SRL) for TO-11A aldehydes

Analyte & Test Data Figure	SRL – Field and Shipping Blanks (ug/sample)	Approximate SRL Samples (ppbV)
Formaldehyde- Figure 90	0.039	1.00
Acetaldehyde- Figure 91	0.039	0.685
Acrolein- Figure 92	0.039	0.538
Acetone- Figure 93	0.039	0.519
Propionaldehyde- Figure 94	0.039	0.519
Crotonaldehyde- Figure 95	0.039	0.430
Methacrolein- Figure 96	0.039	0.430
Methylethylketone & Butyraldehyde- Figure 97	0.039	0.418
Benzaldehyde- Figure 98	0.039	0.284
Valeraldehyde- Figure 99	0.039	0.350

Analyte & Test Data Figure	**SRL – Field and Shipping Blanks (ug/sample)**	**Approximate SRL Samples (ppbV)**
m-Tolualdehyde- Figure 100	0.039	0.251
Hexaldehyde- Figure 101	0.039	0.301

The EPA TO-11A aldehyde results for the injected fluid contaminants at the engine temperatures tested are found in the accompanying dataset within Atmospheric Analysis & Consulting Report Number 221141, Dated June 6, 2022 (KSU, 2024) and its accompanying data file 221141-EPA TO-11-EDD, reported on June 6, 2022 (KSU, 2024). A list of the test conditions sampled and sample identification numbers is presented on page one. Analytical results are presented on pages 2 through 6, and quality control data is presented on pages 7 through 11. The chain of custody forms are presented on pages 12 through 15.

The maximum concentration of aldehyde species present in the lab report are summarized in Table 16. They are depicted by species in Figure 90 through Figure 101.

Table 16. EPA TO-11A results

Aldehyde	**Figure Number**	**Maximum Reported Value (ppbV)**
Formaldehyde	Figure 90	24.5
Acetaldehyde	Figure 91	13.5
Acrolein	Figure 92	4.72
Acetone	Figure 93	6.54
Propionaldehyde	Figure 94	5.17
Crotonaldehyde	Figure 95	4.22
Methacrolein	Figure 96	0.967
Methylethylketone & Butyraldehyde	Figure 97	4.95
Benzaldehyde	Figure 98	0.888
Valeraldehyde	Figure 99	15.8
m-Tolualdehyde	Figure 100	0.796
Hexaldehyde	Figure 101	2.34

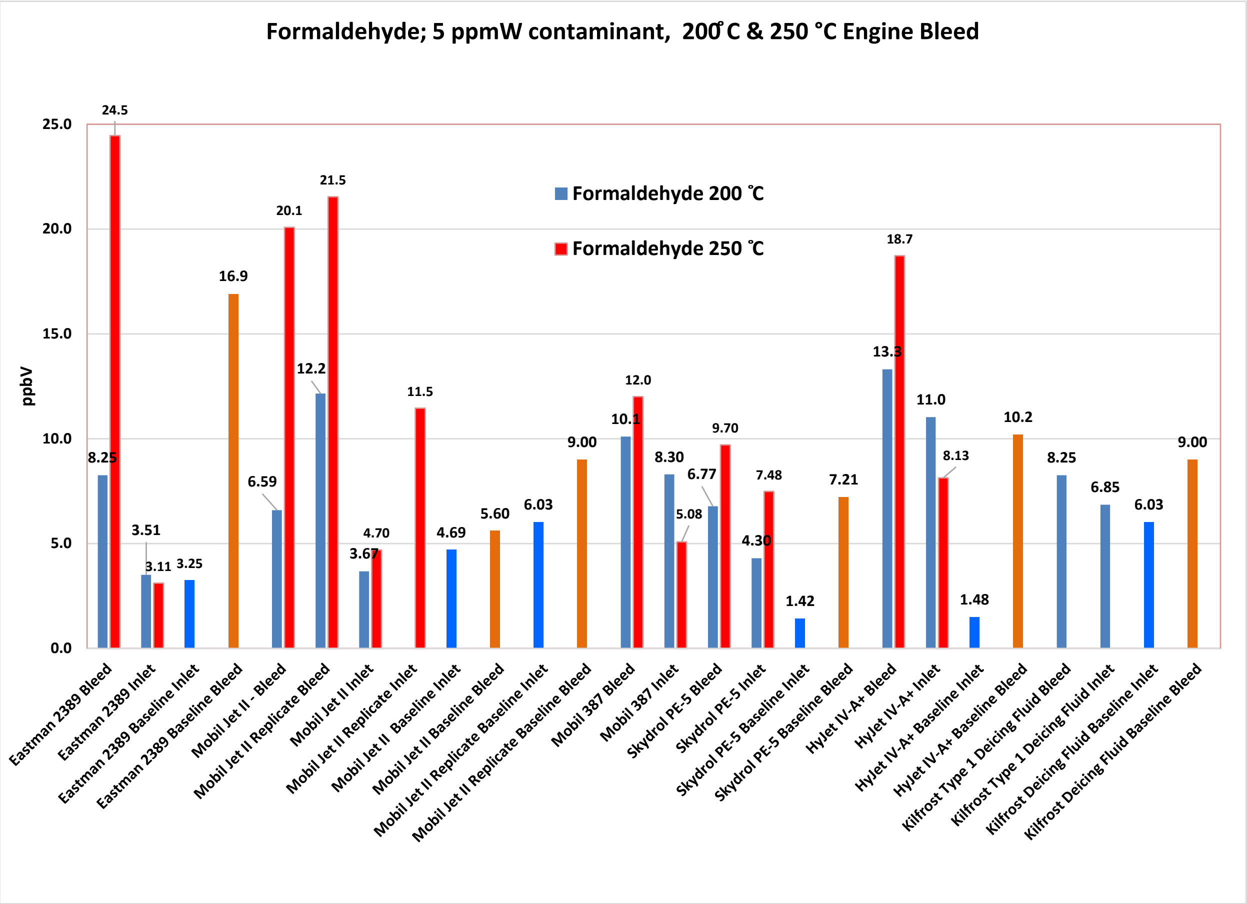


Figure 90. EPA TO-11A response for formaldehyde

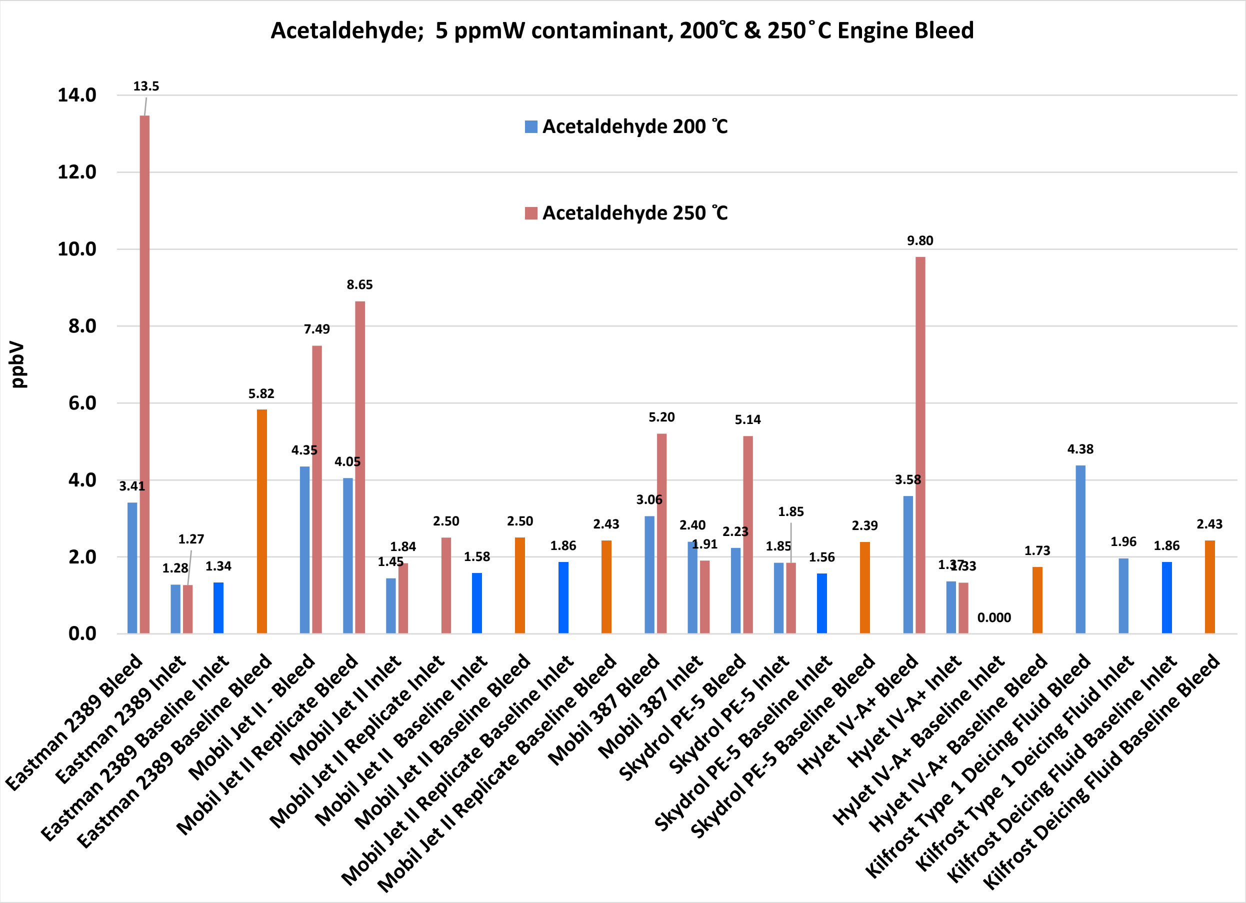


Figure 91. EPA TO-11A Acetaldehyde

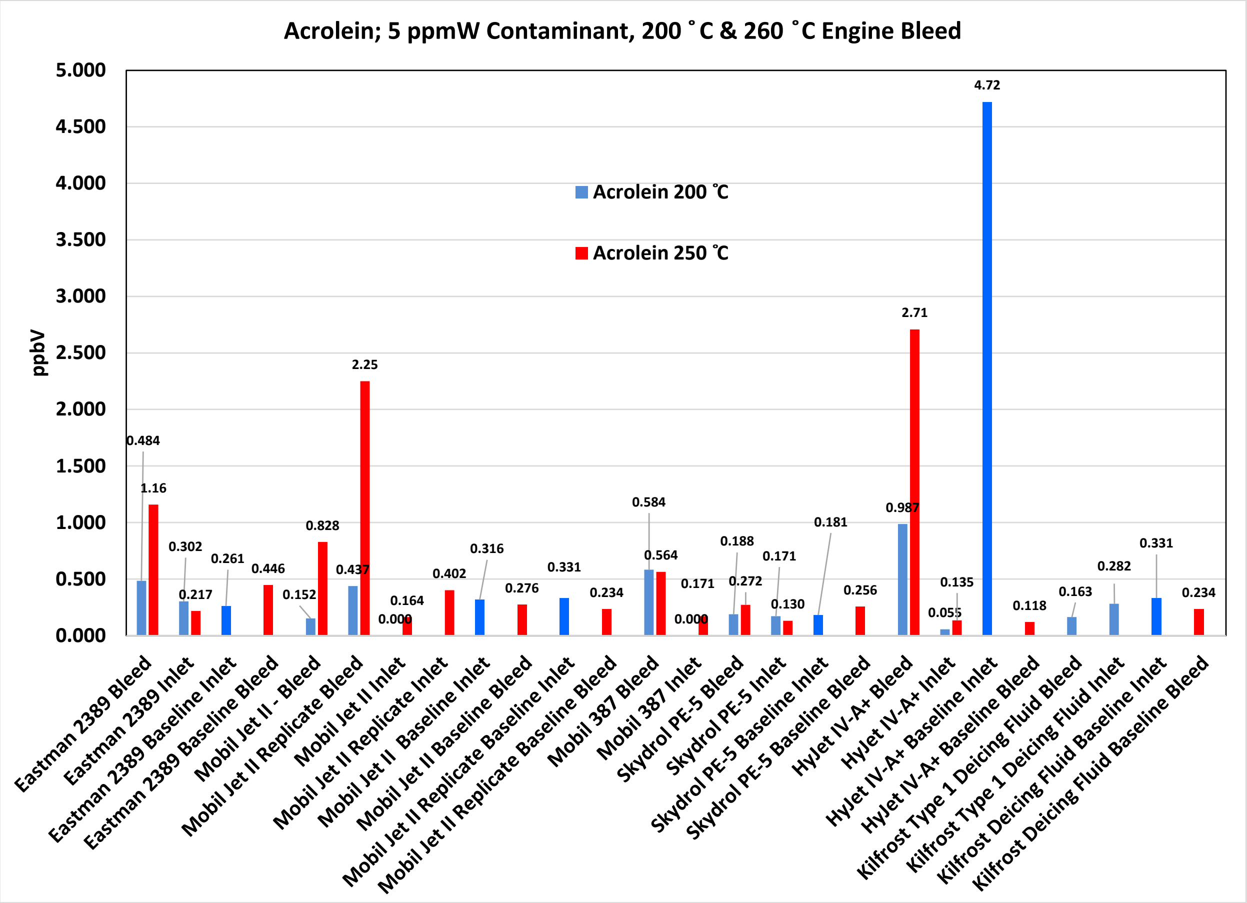


Figure 92. EPA TO-11A Acrolein

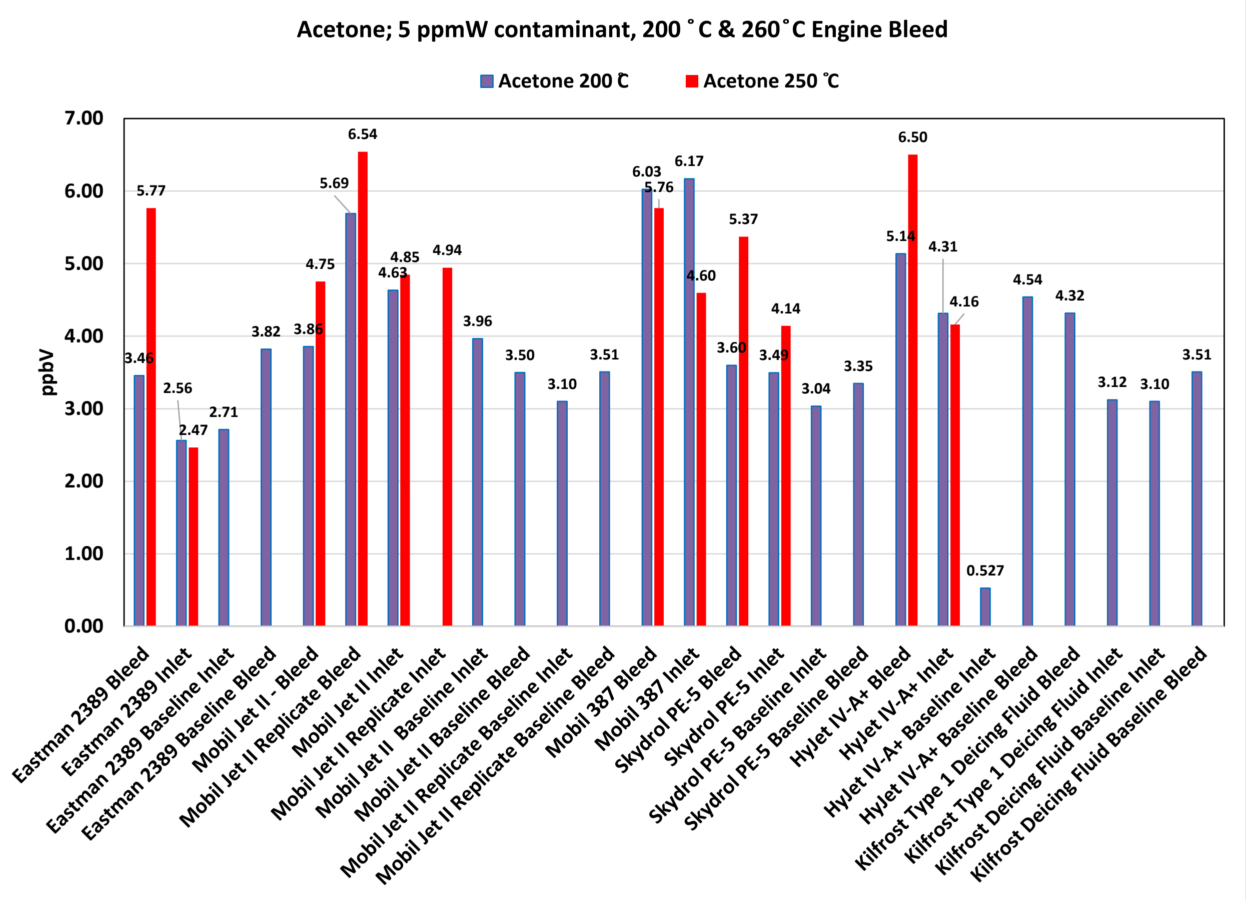


Figure 93. EPA TO-11A Acetone

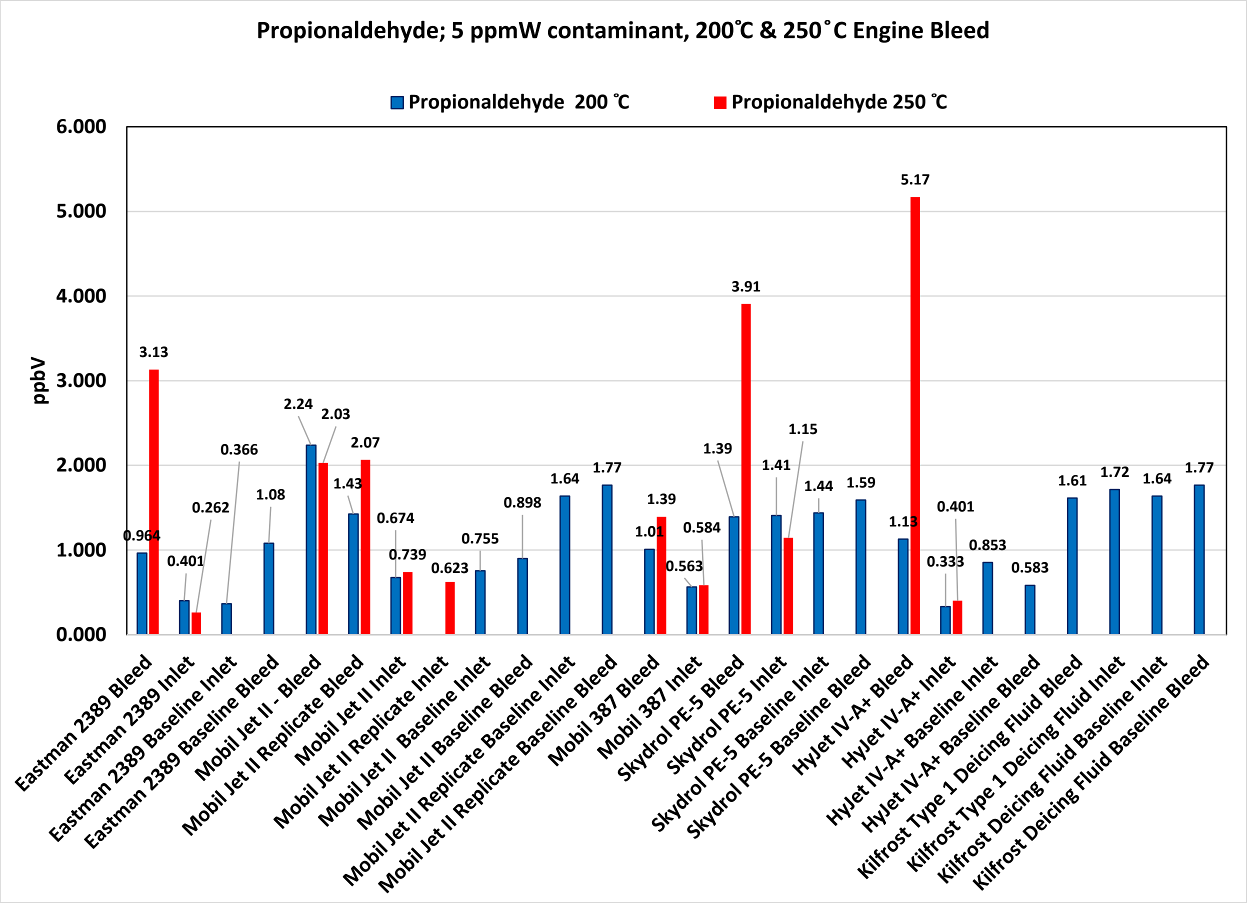


Figure 94. EPA-TO-11A Propionaldehyde

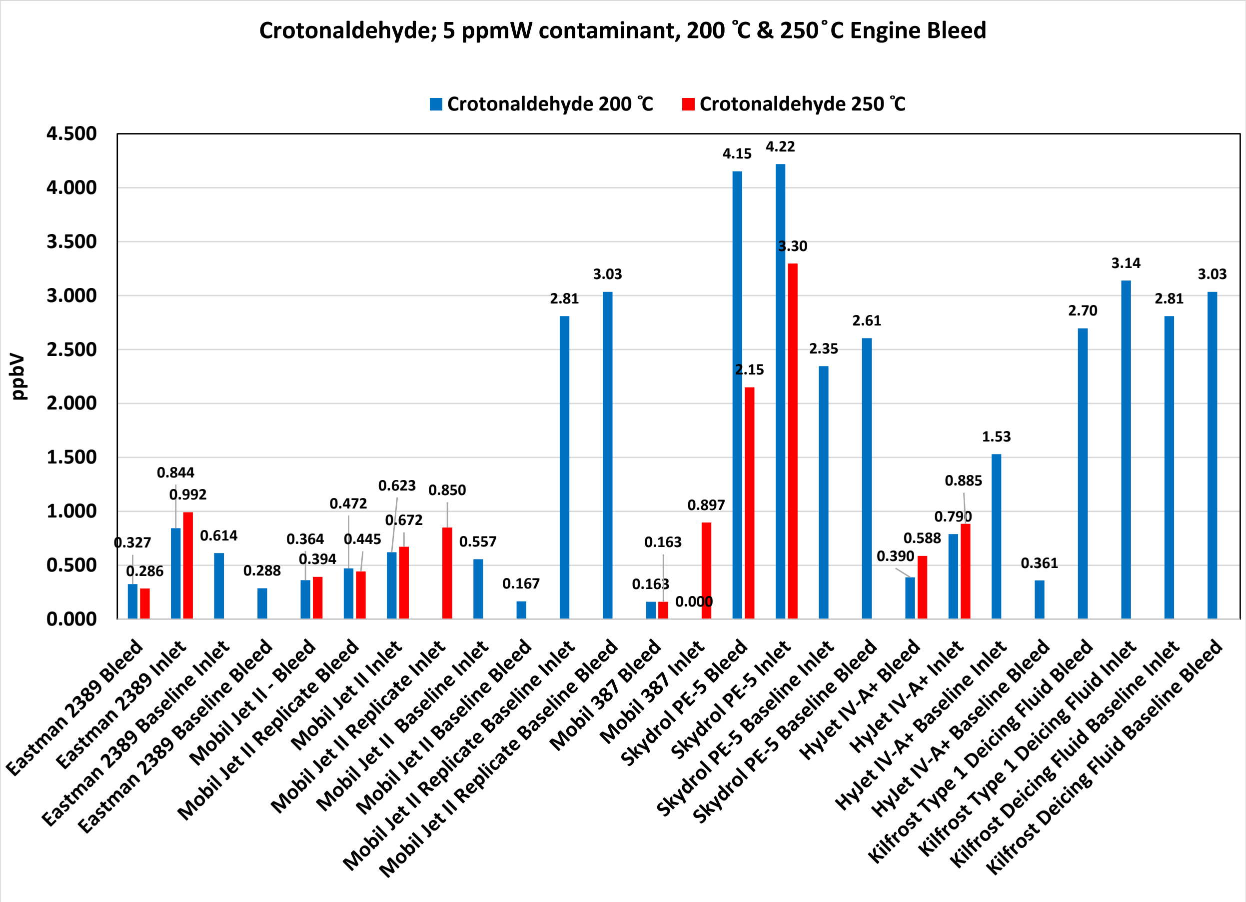


Figure 95. EPA TO-11A Crotonaldehyde

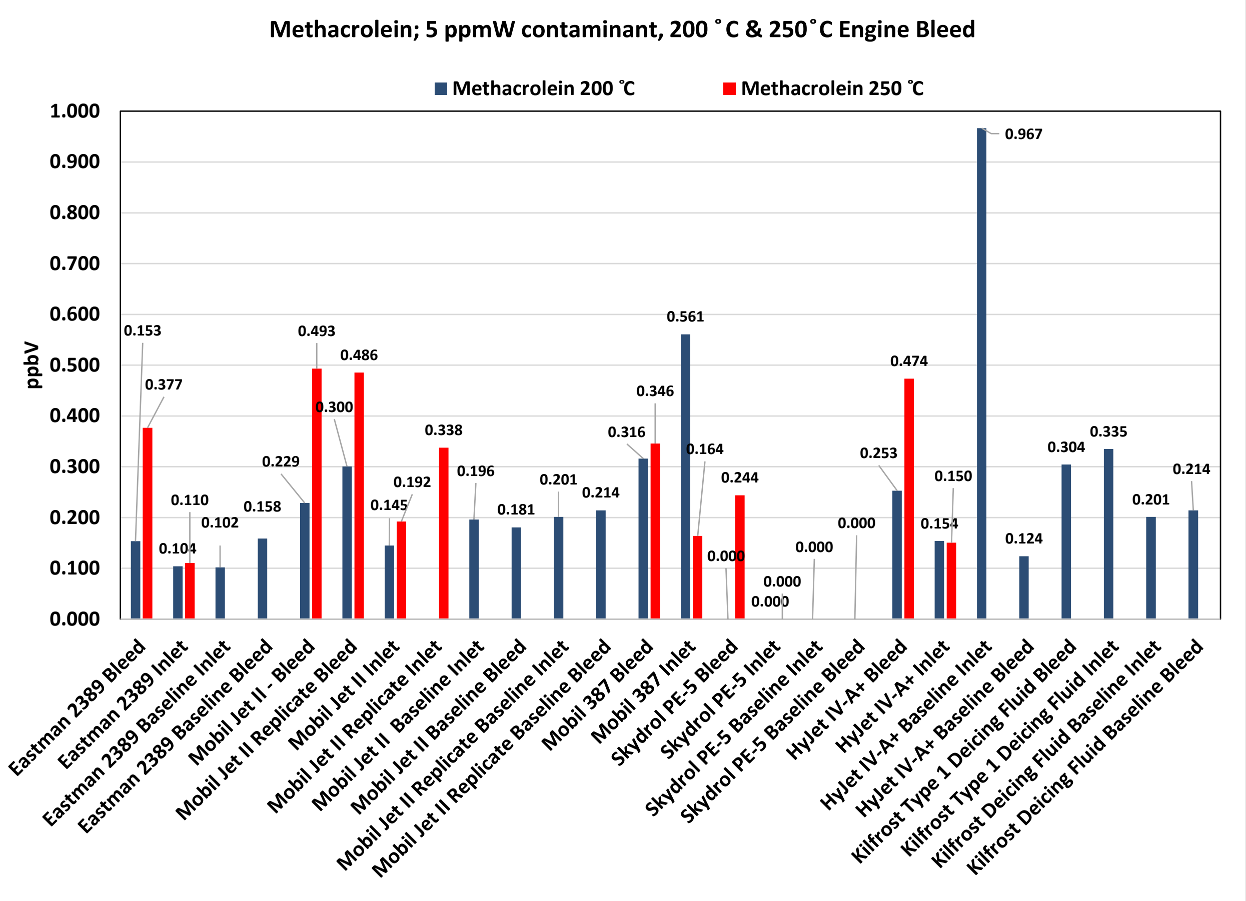


Figure 96. EPA TO-11A Methacrolein

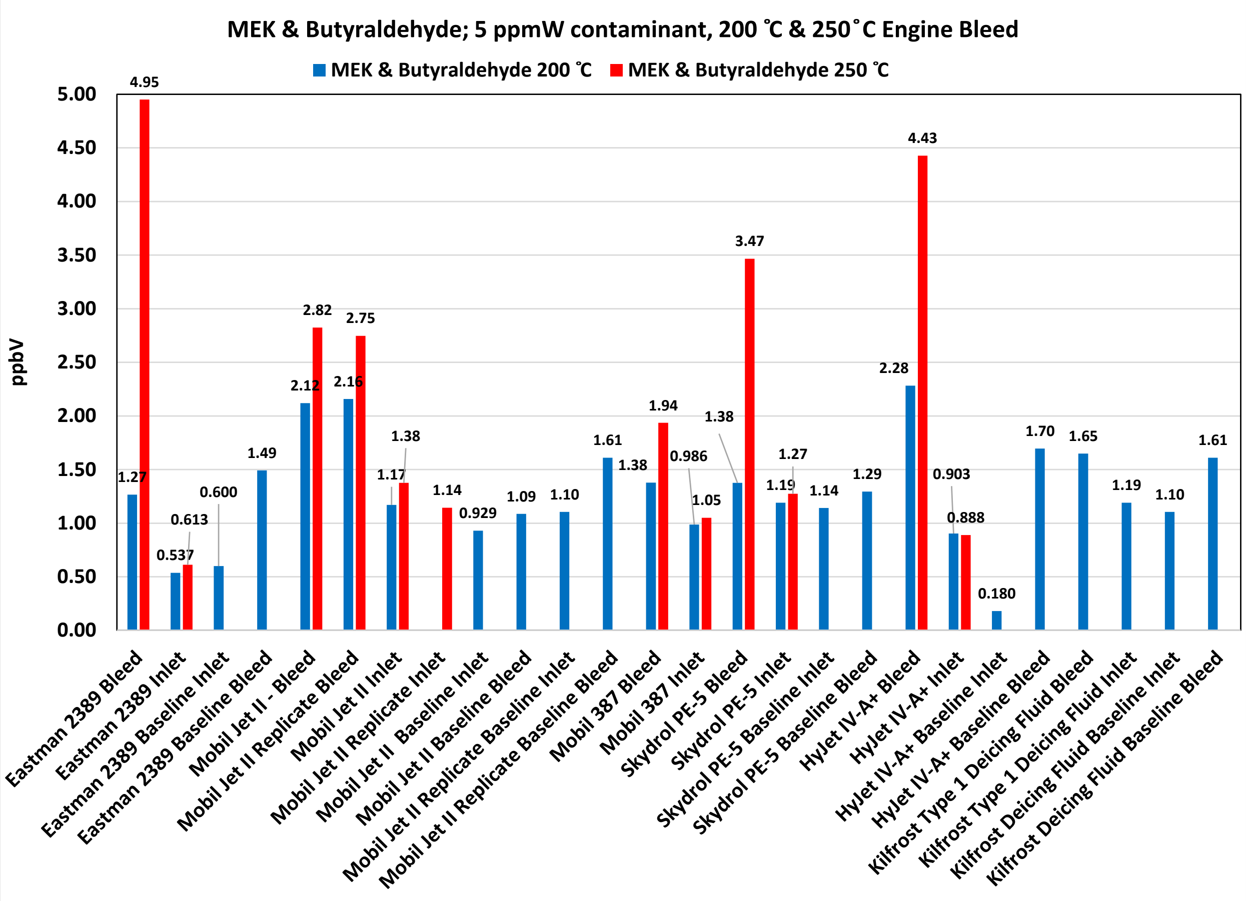


Figure 97. EPA TO-11A MEK and Butyraldehyde

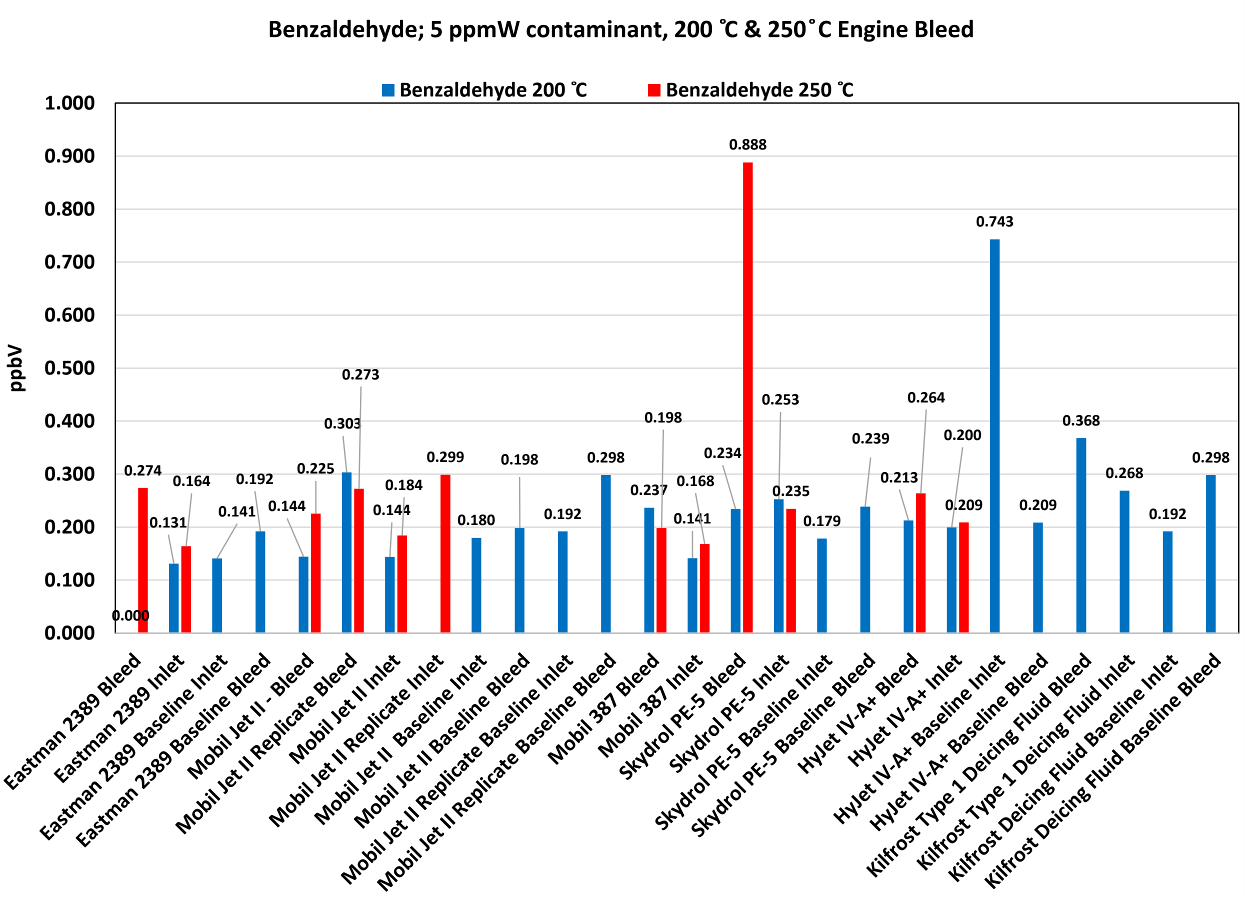


Figure 98. EPA TO-11A Benzaldehyde

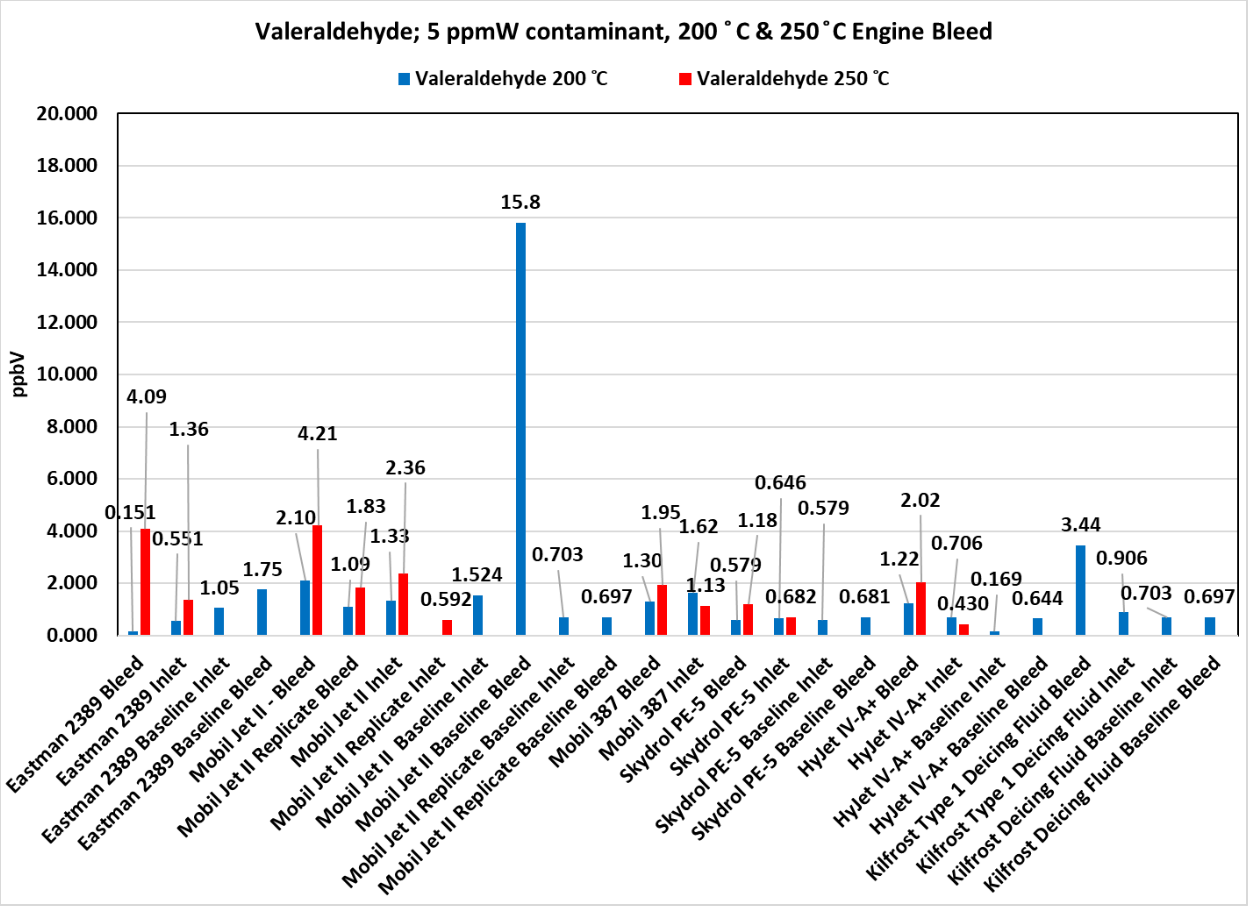


Figure 99. EPA TO-11A Valeraldehyde

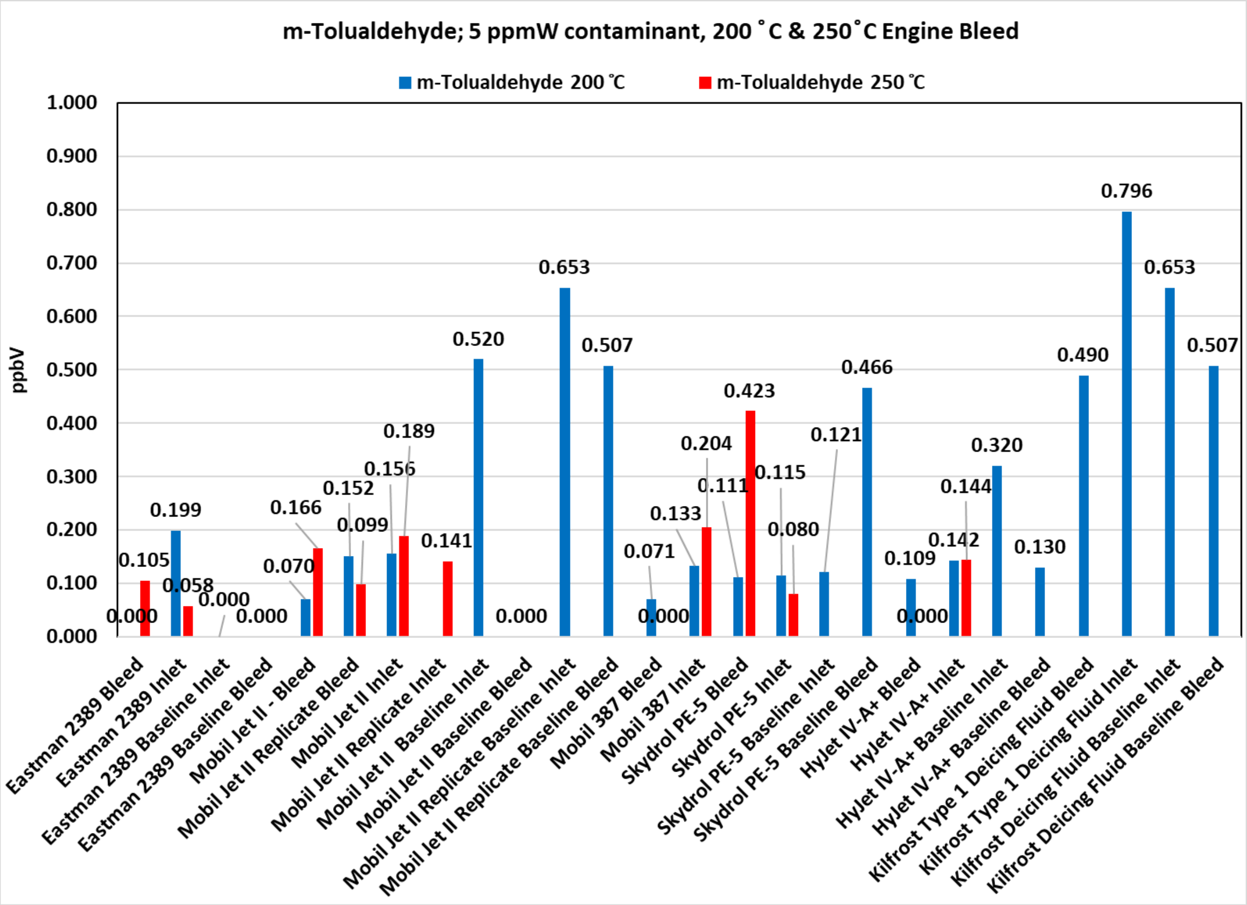


Figure 100. EPA TO-11A m-Tolualdehyde

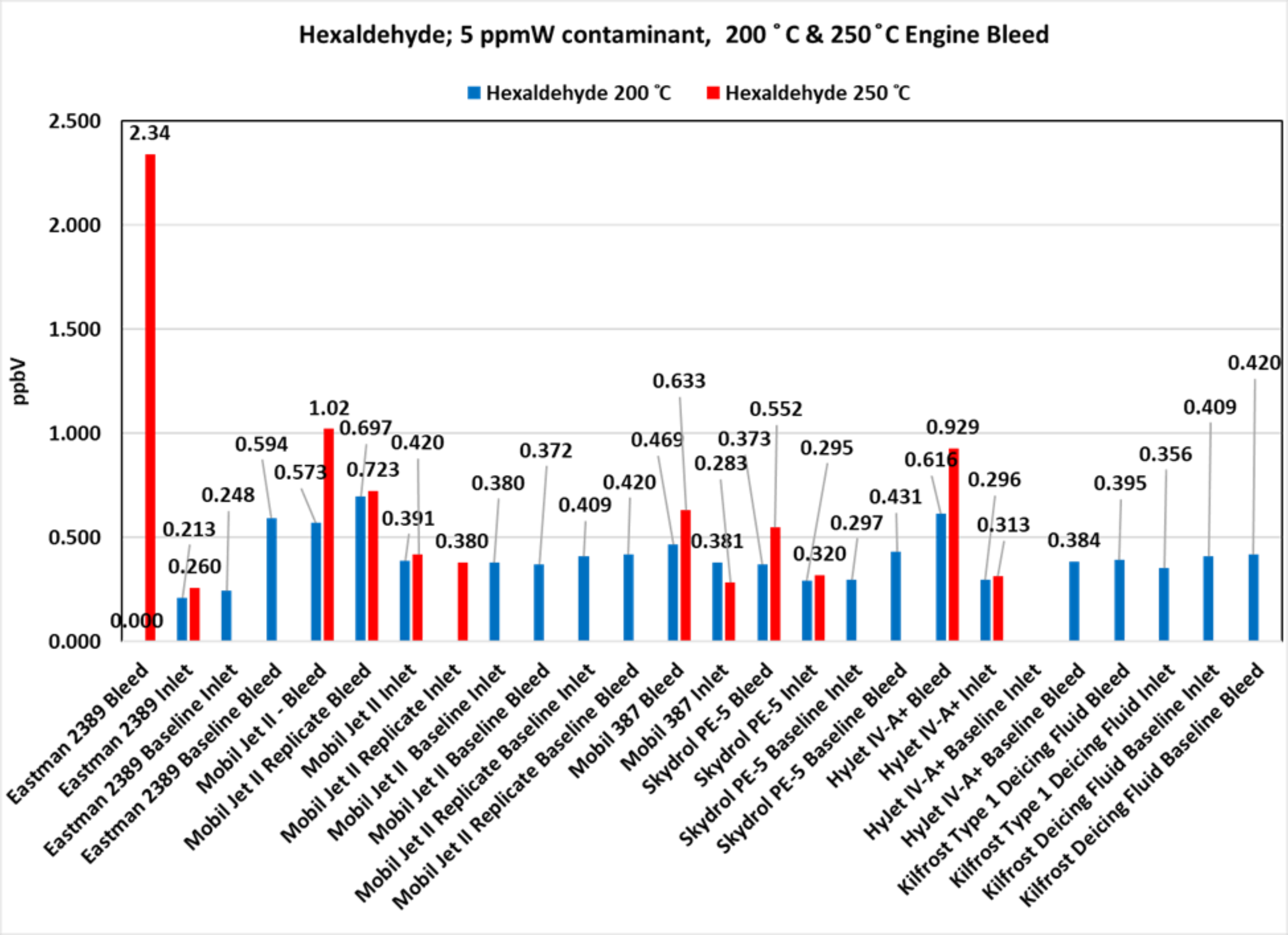
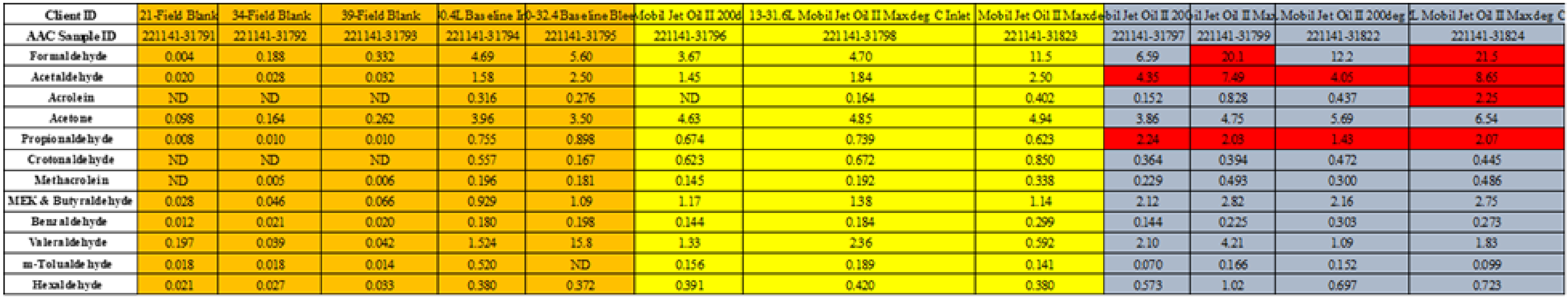


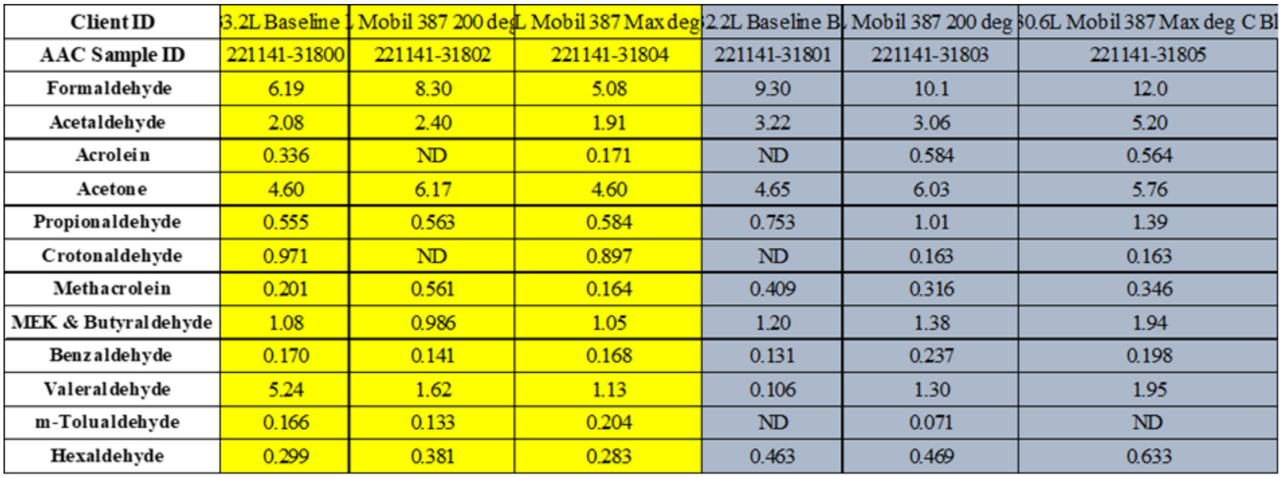
Figure 101. EPA TO-11A Hexaldehyde

A compilation of aldehydes from sampling during Mobil Jet II injection is presented in Figure 102. A compilation of aldehydes measured during Mobil 387 injection is presented in Figure 103. A summary of Skydrol PE-5 aldehydes measured by by EPA TO-11A is presented in Figure 104. A summary of HyJet IV-A aldehydes by EPA TO-11A is presented in Figure 105. A summary of deicing fluid aldehydes by EPA TO-11A is presented in Figure 106. A summary of samples with bleed aldehydes greater than two times the inlet concentration is summarized in Figure 107.



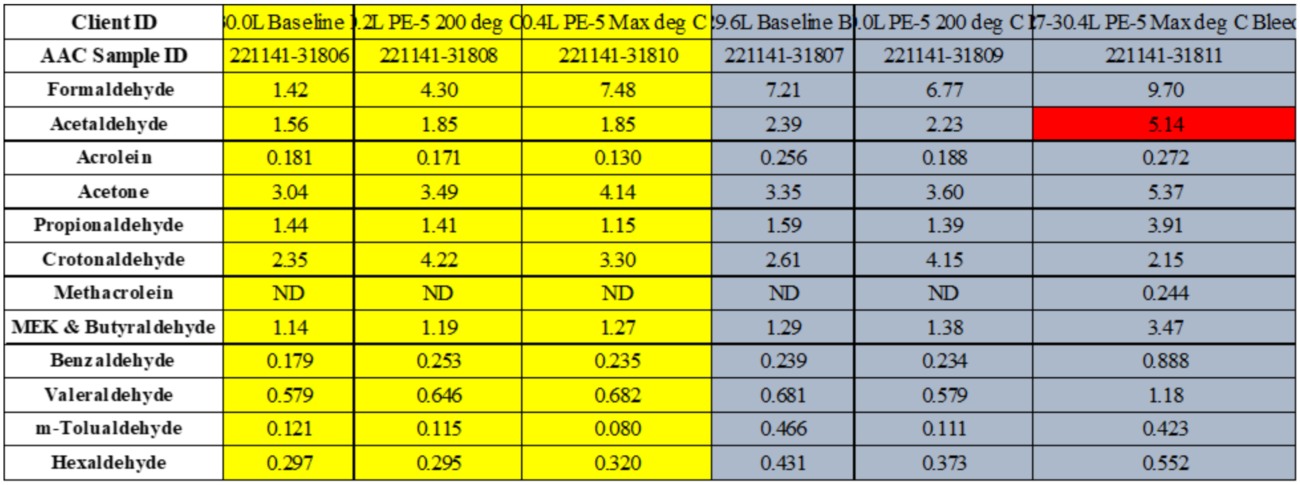
Client ID	21-Field Blank	34-Field Blank	39-Field Blank	0.4L Baseline I	0-32.4 Baseline Blee	obil Jet Oil II 200d	13-31.6L Mobil Jet Oil II Maxdeg C Inlet	Mobil Jet Oil II Maxde	bil Jet Oil II 20	il Jet Oil II Max	Mobil Jet Oil II 200deg	L Mobil Jet Oil II Maxdeg C
AAC Sample ID	221141-31791	221141-31792	221141-31793	221141-31794	221141-31795	221141-31796	221141-31798	221141-31823	221141-31797	221141-31799	221141-31822	221141-31824
Formaldehyde	0.004	0.188	0.332	4.69	5.60	3.67	4.70	11.5	6.59	20.1	12.2	21.5
Acetaldehyde	0.020	0.028	0.032	1.58	2.50	1.45	1.84	2.50	4.35	7.49	4.05	8.65
Acrolein	ND	ND	ND	0.316	0.276	ND	0.164	0.402	0.152	0.828	0.437	2.25
Acetone	0.098	0.164	0.262	3.96	3.50	4.63	4.85	4.94	3.86	4.75	5.69	6.54
Propionaldehyde	0.008	0.010	0.010	0.755	0.898	0.674	0.739	0.623	2.24	2.03	1.43	2.07
Crotonaldehyde	ND	ND	ND	0.557	0.167	0.623	0.672	0.850	0.364	0.394	0.472	0.445
Methacrolein	ND	0.005	0.006	0.196	0.181	0.145	0.192	0.338	0.229	0.493	0.300	0.486
MEK & Butyraldehyde	0.028	0.046	0.066	0.929	1.09	1.17	1.38	1.14	2.12	2.82	2.16	2.75
Benzaldehyde	0.012	0.021	0.020	0.180	0.198	0.144	0.184	0.299	0.144	0.225	0.303	0.273
Valeraldehyde	0.197	0.039	0.042	1.524	15.8	1.33	2.36	0.592	2.10	4.21	1.09	1.83
m-Tolualdehyde	0.018	0.018	0.014	0.520	ND	0.156	0.189	0.141	0.070	0.166	0.152	0.099
Hexaldehyde	0.021	0.027	0.033	0.380	0.372	0.391	0.420	0.380	0.573	1.02	0.697	0.723

Figure 102. Aldehydes detected during injection of Mobil jet II



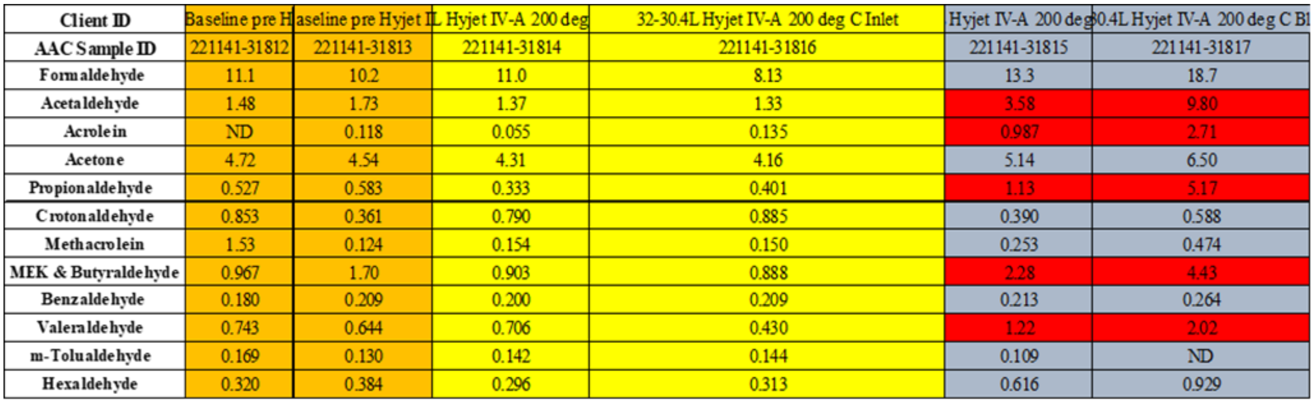
Client ID	3.2L Baseline	Mobil 387 200 deg	L Mobil 387 Max deg	2.2L Baseline B	Mobil 387 200 deg	0.6L Mobil 387 Max deg C Bl
AAC Sample ID	221141-31800	221141-31802	221141-31804	221141-31801	221141-31803	221141-31805
Formaldehyde	6.19	8.30	5.08	9.30	10.1	12.0
Acetaldehyde	2.08	2.40	1.91	3.22	3.06	5.20
Acrolein	0.336	ND	0.171	ND	0.584	0.564
Acetone	4.60	6.17	4.60	4.65	6.03	5.76
Propionaldehyde	0.555	0.563	0.584	0.753	1.01	1.39
Crotonaldehyde	0.971	ND	0.897	ND	0.163	0.163
Methacrolein	0.201	0.561	0.164	0.409	0.316	0.346
MEK & Butyraldehyde	1.08	0.986	1.05	1.20	1.38	1.94
Benzaldehyde	0.170	0.141	0.168	0.131	0.237	0.198
Valeraldehyde	5.24	1.62	1.13	0.106	1.30	1.95
m-Tolualdehyde	0.166	0.133	0.204	ND	0.071	ND
Hexaldehyde	0.299	0.381	0.283	0.463	0.469	0.633

Figure 103. Aldehydes detected during injection of Mobil 387



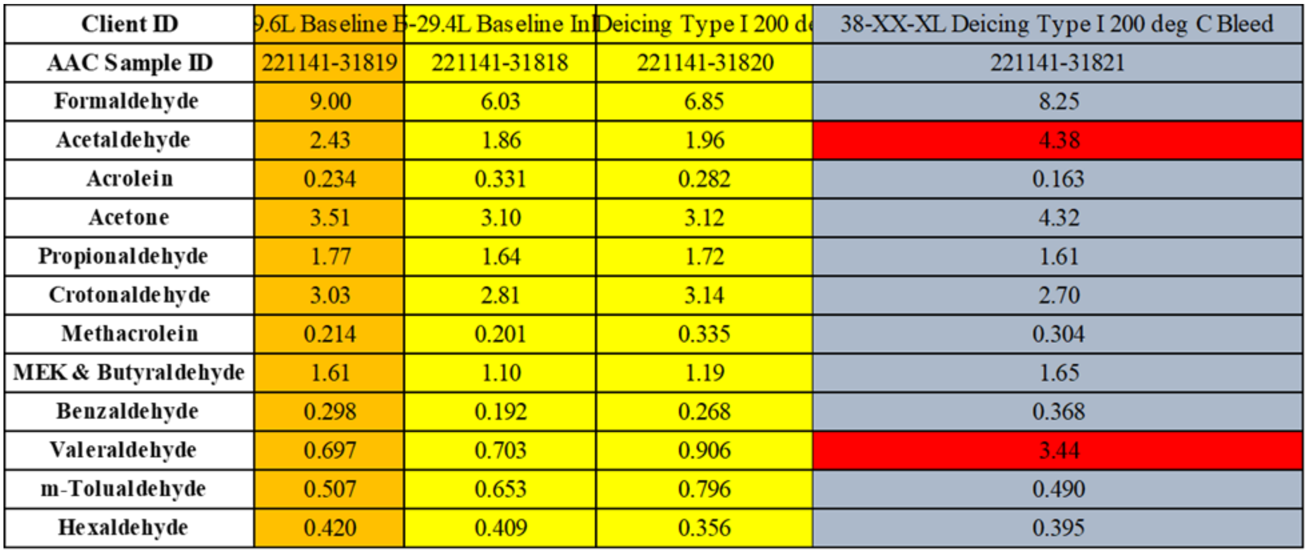
Client ID	0.0L Baseline	.2L PE-5 200 deg C	0.4L PE-5 Max deg C	9.6L Baseline B	.0L PE-5 200 deg C	7-30.4L PE-5 Max deg C Blee
AAC Sample ID	221141-31806	221141-31808	221141-31810	221141-31807	221141-31809	221141-31811
Formaldehyde	1.42	4.30	7.48	7.21	6.77	9.70
Acetaldehyde	1.56	1.85	1.85	2.39	2.23	5.14
Acrolein	0.181	0.171	0.130	0.256	0.188	0.272
Acetone	3.04	3.49	4.14	3.35	3.60	5.37
Propionaldehyde	1.44	1.41	1.15	1.59	1.39	3.91
Crotonaldehyde	2.35	4.22	3.30	2.61	4.15	2.15
Methacrolein	ND	ND	ND	ND	ND	0.244
MEK & Butyraldehyde	1.14	1.19	1.27	1.29	1.38	3.47
Benzaldehyde	0.179	0.253	0.235	0.239	0.234	0.888
Valeraldehyde	0.579	0.646	0.682	0.681	0.579	1.18
m-Tolualdehyde	0.121	0.115	0.080	0.466	0.111	0.423
Hexaldehyde	0.297	0.295	0.320	0.431	0.373	0.552

Figure 104. Summary: Skydrol PE-5 Aldehydes measured by EPA TO-11A



Client ID	Baseline pre H	aseline pre Hyjet I	L Hyjet IV-A 200 deg	32-30.4L Hyjet IV-A 200 deg C Inlet	Hyjet IV-A 200 deg	30.4L Hyjet IV-A 200 deg C Bl
AAC Sample ID	221141-31812	221141-31813	221141-31814	221141-31816	221141-31815	221141-31817
Formaldehyde	11.1	10.2	11.0	8.13	13.3	18.7
Acetaldehyde	1.48	1.73	1.37	1.33	3.58	9.80
Acrolein	ND	0.118	0.055	0.135	0.987	2.71
Acetone	4.72	4.54	4.31	4.16	5.14	6.50
Propionaldehyde	0.527	0.583	0.333	0.401	1.13	5.17
Crotonaldehyde	0.853	0.361	0.790	0.885	0.390	0.588
Methacrolein	1.53	0.124	0.154	0.150	0.253	0.474
MEK & Butyraldehyde	0.967	1.70	0.903	0.888	2.28	4.43
Benzaldehyde	0.180	0.209	0.200	0.209	0.213	0.264
Valeraldehyde	0.743	0.644	0.706	0.430	1.22	2.02
m-Tolualdehyde	0.169	0.130	0.142	0.144	0.109	ND
Hexaldehyde	0.320	0.384	0.296	0.313	0.616	0.929

Figure 105. Summary of HyJet IV-A aldehydes by EPA TO-11A



Client ID	9.6L Baseline B	-29.4L Baseline In	Deicing Type I 200 de	38-XX-XL Deicing Type I 200 deg C Bleed
AAC Sample ID	221141-31819	221141-31818	221141-31820	221141-31821
Formaldehyde	9.00	6.03	6.85	8.25
Acetaldehyde	2.43	1.86	1.96	4.38
Acrolein	0.234	0.331	0.282	0.163
Acetone	3.51	3.10	3.12	4.32
Propionaldehyde	1.77	1.64	1.72	1.61
Crotonaldehyde	3.03	2.81	3.14	2.70
Methacrolein	0.214	0.201	0.335	0.304
MEK & Butyraldehyde	1.61	1.10	1.19	1.65
Benzaldehyde	0.298	0.192	0.268	0.368
Valeraldehyde	0.697	0.703	0.906	3.44
m-Tolualdehyde	0.507	0.653	0.796	0.490
Hexaldehyde	0.420	0.409	0.356	0.395

Figure 106. Summary of Deicing Fluid aldehydes by EPA TO-11A

Aldehyde	200 C	Max Bleed
Formaldehyde	Eastman 2389	Eastman 2389 Mobil Jet II
Acetaldehyde	Eastman 2389 Mobil Jet II Eastman HyJet IV-A+ Type I Deicing Fluid	Eastman 2389 Mobil Jet II Skydrol PE-5 Eastman HyJet IV-A+
Butyraldehyde	Eastman 2389	Eastman 2389
Valeraldehyde	Eastman HyJet IV-A+ Type I Deicing Fluid	Eastman 2389 Eastman HyJet IV-A+
Hexaldehdye		Eastman 2389
Acrolein	Eastman HyJet IV-A+	Mobil Jet II Eastman HyJet IV-A+
Propionaldehyde	Eastman HyJet IV-A+	Mobil Jet II Eastman HyJet IV-A+

Figure 107. EPA TO-11A Aldehyde samples in which the bleed was > twice the inlet level

3.2.2 EPA TO-13A polycyclic aromatic hydrocarbons (PAH)

EPA Method TO-13A is for the determination of polycyclic aromatic hydrocarbons (EPA, 1999). The major sorbent for the method is polyurethane foam (PUF). The secondary sorbent is XAD-2® resin. The method is developed for analysis of the following polycyclic aromatic hydrocarbons (PAH) using a high-volume sampler capable of pulling ambient air through the filter/sorbet cartridge “at a flow rate of 8 standard cubic feet per minute (scfm) (0.225 std m^3/min) to obtain a total sample volume of greater than 300 m3 over a 24-hour period. With optimization to reagent purity and analytical conditions, the detection limits for the GC/MS method range from 1 ng to 10 pg based on field experience” (EPA, 1999).

Applicable compounds for this method include: Acenaphthene, Acenaphthylene, Anthracene, Benz(a)anthracene, Benzo(a)pyrene, BenzoIpyrene, Benzo (g, h, i) perylene, Benzo(k)fluoranthene, Chrysene, Coronene, Dibenz (a, h) anthracene, Fluoranthene, Fluorene, Benzo(b)fluoranthene, Indeno (1,2,3-cd) pyrene, Naphthalene, Phenanthrene, Pyrene, and Perylene. Standards are run in the instrument to provide quantitative results for these compounds.

Most of the compounds detected by this method are not on the primary list for EPA TO-13A method but are detected by performing a total ion scan to characterize tentatively identified compounds (TICS). Surrogate standards are run with the analysis to obtain semi-quantitative concentrations. These results are based on how well the chromatograms match up with compounds in a chromatographic library, so they are not confirmed compounds, but are likely compounds. The full EPA TO-13 data set is summarized in Figure 112 through Figure 117 and found in RJ Lee Laboratory Report W205131 EDD, which is contained in the supporting dataset for this report.

- Figure 112. EPA TO-13 target compound list
- Figure 113. EPA TO-13 shipping blank results summary
- Figure 114. EPA TO-13A field blank results summary
- Figure 115. EPA TO-13A baseline inlet and bleed results: Eastman 2389 & Mobil 387
- Figure 116. EPA TO-13A Eastman 2389 results summary
- Figure 117. Summary of EPA TO-13A baseline inlet & bleed air contaminants detected for HyJet IV-A and Skydrol PE-5

The analytical reports for all samples include:

1. Results in units of micrograms of analyte per sample (ug/sample)
2. Parts per billion volume (ppbV), and 3) micrograms per cubic meter (ug/m3)

The confidence interval for all reporting units is the same, 70-130%. The probability (certainty) of the compound identification for the TICs is listed in the ‘Qualifier’ column. It appears as a numerical value from 0-100, as percent quality fit between the unknown and the library spectrum. A fit of ‘0’ is an additional indication that the chromatographic peak/mass spectrum was an unknown with a mass spectrum that was not in the NIST library. The library used was the NIST 2020 Revision. The apparent low concentration in PUF/XAD samples was noted during the analysis. The quartz filters will show a significantly higher level of material, indicating that most of the analytes of interest were either present in particles, droplets, or sufficiently non-volatile as to precipitate onto the quartz filters. Some of the samples required dilution to bring the concentration of a couple of the target analytes into the range of the calibration curve. These sample results will have the ‘D’ qualifier in the ‘Qualifier’ column.

The polycylic aromatic compounds and tentatively identified compound results for PUF/XAD sample media are found in RJ Lee Laboratory Report Number 205131, Revision 1 (KSU, 2024) and Report Number 205177, Revision 1 (KSU, 2024).

In addition, there are two accompanying excel files containing the sample information and method detection limits in tabular format. The EDD file names are W205131 EDD Rev1 and 205177 EDD Rev1. Table 17 summarizes the contents of these files.

RJ Lee Laboratory made a verbal assessment of the quantity of analyte found on PUF/XAD cartridges compared to quartz filters. They found the quarts filters located above the PUF/XAD cartridges intercepted almost all of the semi volatile and particulate, thus resulting in very low quantitation values for analytes on the PUF/XAD cartridges.

Table 17. Summary of EPA TO-13A file contents

RJ Lee Report Number/Revision	Report Date	Sample Numbers	Quality Control Report Pages	Chain of Custody and Lab ID Pages	Chromatograms Pages
W205131, Rev 1	November 23, 2023	2-14	41-45	46-50	51-64
W205177, Rev 1	November 16, 2023	15-30	45-49	64-68	50-63
W205131 EDD Rev 1	November 23, 2023	2-14			
W205177 EDD Rev 1	November 28, 2023	15-30			

3.2.3 EPA TO-15 volatile organic compounds (VOCs) - air sampling method

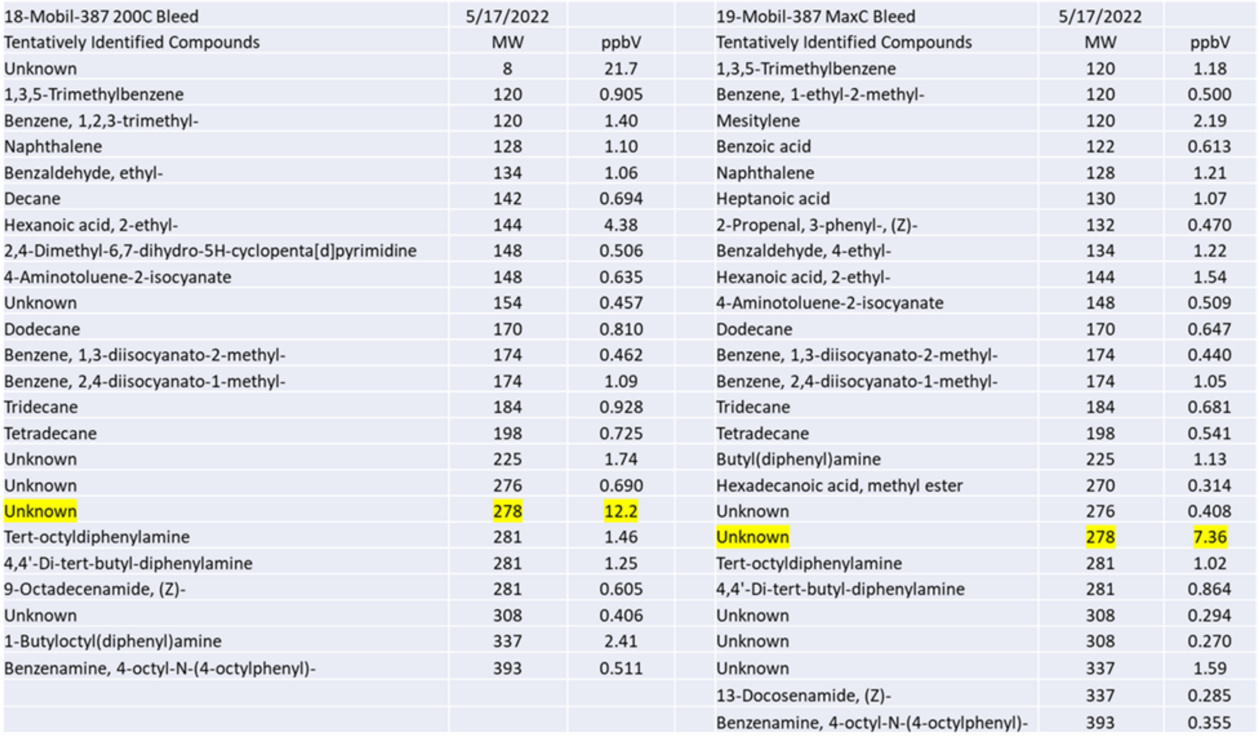
EPA TO-15 is a Summa ® Canister (evacuated canister) sampling method (EPA, 1999). The U.S. EPA method detection list for the EPA TO-15 target compounds is presented in Figure 110. Laboratory chemical analyses for method EPA TO-15 were conducted by AAC Laboratories in Ventura, California. The reports for this method are found in report numbers 221095 and 221106. These reports are included in the supporting dataset for this report.

Analytes from the EPA TO-15 were superimposed over the analyte detection list (Table 18) found in the Alphasense® Application Note AAN 305-06 (Alphasense LTD, 2017). It is noteworthy that after reviewing PID results in the instrument results section, and then referring to the minimum detection limits in Table 18 that the PID would have challenges sensing contaminants at the level reported by the EPA TO-15 method in this study. There is no doubt that the PID did respond to certain test conditions.

A summary of the primary compounds and the test contaminant samples in which they were present is found in Figure 111.

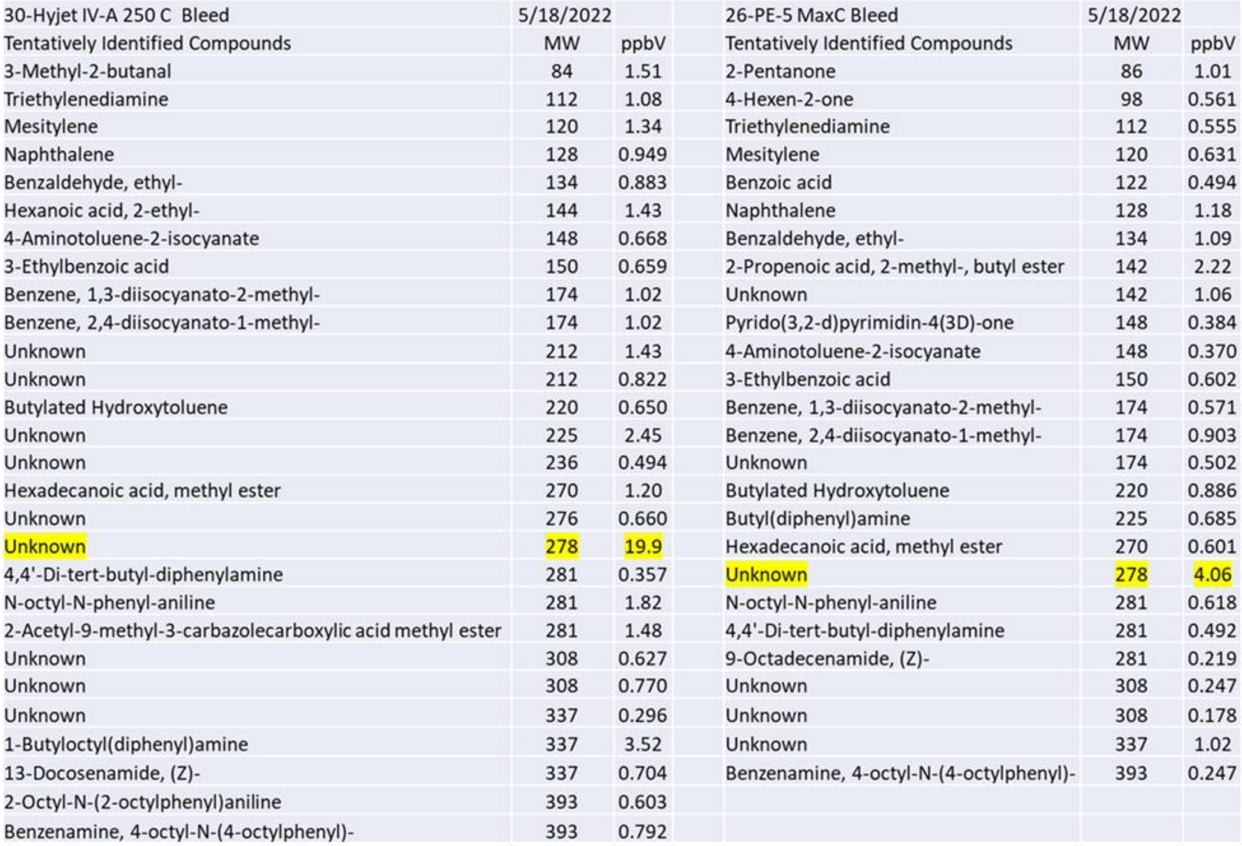
A summary of compounds measured by EPA TO-13 during baseline sampling before Mobil 387 injection is presented in Figure 108.

A summary of compounds measured by EPA TO-13 while sampling during Mobil 387 injection is presented in Figure 109.



18-Mobil-387 200C Bleed	5/17/2022		19-Mobil-387 MaxC Bleed	5/17/2022	
Tentatively Identified Compounds	MW	ppbV	Tentatively Identified Compounds	MW	ppbV
Unknown	8	21.7	1,3,5-Trimethylbenzene	120	1.18
1,3,5-Trimethylbenzene	120	0.905	Benzene, 1-ethyl-2-methyl-	120	0.500
Benzene, 1,2,3-trimethyl-	120	1.40	Mesitylene	120	2.19
Naphthalene	128	1.10	Benzoic acid	122	0.613
Benzaldehyde, ethyl-	134	1.06	Naphthalene	128	1.21
Decane	142	0.694	Heptanoic acid	130	1.07
Hexanoic acid, 2-ethyl-	144	4.38	2-Propenal, 3-phenyl-, (Z)-	132	0.470
2,4-Dimethyl-6,7-dihydro-5H-cyclopenta[d]pyrimidine	148	0.506	Benzaldehyde, 4-ethyl-	134	1.22
4-Aminotoluene-2-isocyanate	148	0.635	Hexanoic acid, 2-ethyl-	144	1.54
Unknown	154	0.457	4-Aminotoluene-2-isocyanate	148	0.509
Dodecane	170	0.810	Dodecane	170	0.647
Benzene, 1,3-diisocyanato-2-methyl-	174	0.462	Benzene, 1,3-diisocyanato-2-methyl-	174	0.440
Benzene, 2,4-diisocyanato-1-methyl-	174	1.09	Benzene, 2,4-diisocyanato-1-methyl-	174	1.05
Tridecane	184	0.928	Tridecane	184	0.681
Tetradecane	198	0.725	Tetradecane	198	0.541
Unknown	225	1.74	Butyl(diphenyl)amine	225	1.13
Unknown	276	0.690	Hexadecanoic acid, methyl ester	270	0.314
Unknown	278	12.2	Unknown	276	0.408
Tert-octyldiphenylamine	281	1.46	Unknown	278	7.36
4,4'-Di-tert-butyl-diphenylamine	281	1.25	Tert-octyldiphenylamine	281	1.02
9-Octadecenamide, (Z)-	281	0.605	4,4'-Di-tert-butyl-diphenylamine	281	0.864
Unknown	308	0.406	Unknown	308	0.294
1-Butyloctyl(diphenyl)amine	337	2.41	Unknown	308	0.270
Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	0.511	Unknown	337	1.59
			13-Docosenamide, (Z)-	337	0.285
			Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	0.355

Figure 108. Summary of EPA TO-13 A compounds detected during baseline sampling before Mobil 387 injection



30-Hyjet IV-A 250 C Bleed	5/18/2022	
Tentatively Identified Compounds	MW	ppbV
3-Methyl-2-butanal	84	1.51
Triethylenediamine	112	1.08
Mesitylene	120	1.34
Naphthalene	128	0.949
Benzaldehyde, ethyl-	134	0.883
Hexanoic acid, 2-ethyl-	144	1.43
4-Aminotoluene-2-isocyanate	148	0.668
3-Ethylbenzoic acid	150	0.659
Benzene, 1,3-diisocyanato-2-methyl-	174	1.02
Benzene, 2,4-diisocyanato-1-methyl-	174	1.02
Unknown	212	1.43
Unknown	212	0.822
Butylated Hydroxytoluene	220	0.650
Unknown	225	2.45
Unknown	236	0.494
Hexadecanoic acid, methyl ester	270	1.20
Unknown	276	0.660
Unknown	278	19.9
4,4'-Di-tert-butyl-diphenylamine	281	0.357
N-octyl-N-phenyl-aniline	281	1.82
2-Acetyl-9-methyl-3-carbazolecarboxylic acid methyl ester	281	1.48
Unknown	308	0.627
Unknown	308	0.770
Unknown	337	0.296
1-Butyloctyl(diphenyl)amine	337	3.52
13-Docosenamide, (Z)-	337	0.704
2-Octyl-N-(2-octylphenyl)aniline	393	0.603
Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	0.792

26-PE-5 MaxC Bleed	5/18/2022	
Tentatively Identified Compounds	MW	ppbV
2-Pentanone	86	1.01
4-Hexen-2-one	98	0.561
Triethylenediamine	112	0.555
Mesitylene	120	0.631
Benzoic acid	122	0.494
Naphthalene	128	1.18
Benzaldehyde, ethyl-	134	1.09
2-Propenoic acid, 2-methyl-, butyl ester	142	2.22
Unknown	142	1.06
Pyrido(3,2-d)pyrimidin-4(3D)-one	148	0.384
4-Aminotoluene-2-isocyanate	148	0.370
3-Ethylbenzoic acid	150	0.602
Benzene, 1,3-diisocyanato-2-methyl-	174	0.571
Benzene, 2,4-diisocyanato-1-methyl-	174	0.903
Unknown	174	0.502
Butylated Hydroxytoluene	220	0.886
Butyl(diphenyl)amine	225	0.685
Hexadecanoic acid, methyl ester	270	0.601
Unknown	278	4.06
N-octyl-N-phenyl-aniline	281	0.618
4,4'-Di-tert-butyl-diphenylamine	281	0.492
9-Octadecenamide, (Z)-	281	0.219
Unknown	308	0.247
Unknown	308	0.178
Unknown	337	1.02
Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	0.247

Figure 109. Summary of EPA TO-13A compounds during Sample Injection for Mobil 387

TO-14A List	Lab #1, SCAN	Lab #2, SIM
Benzene	0.34	0.29
Benzyl Chloride	--	--
Carbon tetrachloride	0.42	0.15
Chlorobenzene	0.34	0.02
Chloroform	0.25	0.07
1,3-Dichlorobenzene	0.36	0.07
1,2-Dibromoethane	--	0.05
1,4-Dichlorobenzene	0.70	0.12
1,2-Dichlorobenzene	0.44	--
1,1-Dichloroethane	0.27	0.05
1,2-Dichloroethane	0.24	--
1,1-Dichloroethene	--	0.22
cis-1,2-Dichloroethene	--	0.06
Methylene chloride	1.38	0.84
1,2-Dichloropropane	0.21	--
cis-1,3-Dichloropropene	0.36	--
trans-1,3-Dichloropropene	0.22	--
Ethylbenzene	0.27	0.05
Chloroethane	0.19	--
Trichlorofluoromethane	--	--
1,1,2-Trichloro-1,2,2-trifluoroethane		--
1,2-Dichloro-1,1,2,2-tetrafluoroethane	--	--
Dichlorodifluoromethane	--	--
Hexachlorobutadiene	--	--
Bromomethane	0.53	--
Chloromethane	0.40	--
Styrene	1.64	0.06
1,1,2,2-Tetrachloroethane	0.28	0.09
Tetrachloroethene	0.75	0.10
Toluene	0.99	0.20
1,2,4-Trichlorobenzene	--	--
1,1,1-Trichloroethane	0.62	0.21
1,1,2-Trichloroethane	0.50	--
Trichloroethene	0.45	0.07
1,2,4-Trimethylbenzene	--	--
1,3,5-Trimethylbenzene	--	--
Vinyl Chloride	0.33	0.48
m,p-Xylene	0.76	0.08
o-Xylene	0.57	0.28

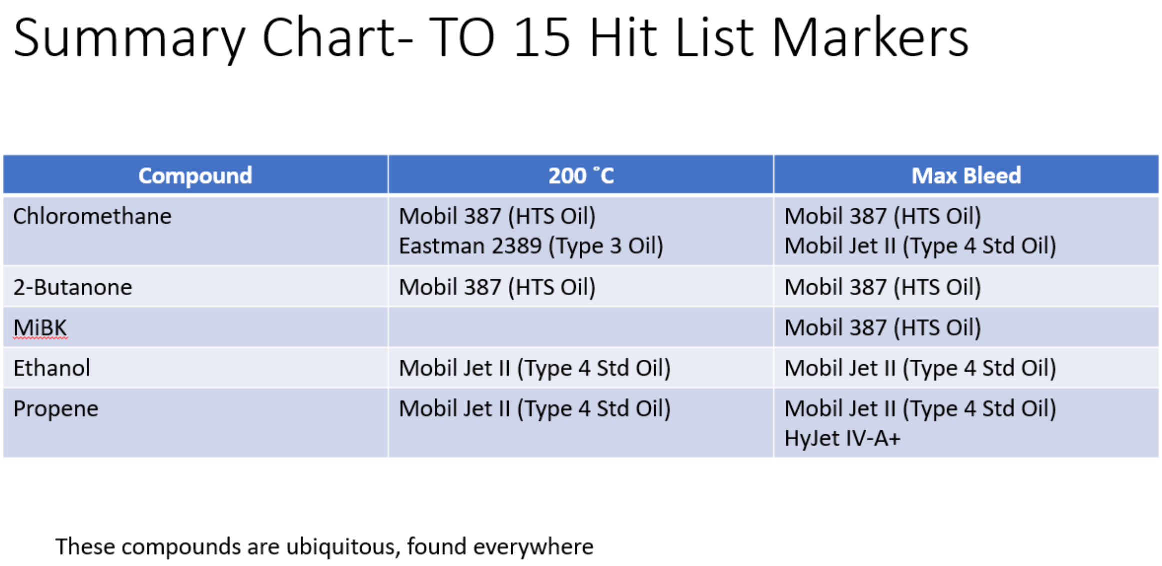
[1] Method Detection Limits (MDLs) are defined as the product of the standard deviation of seven replicate analyses and the student's "t" test value for 99% confidence. For Lab #2, the MDLs represent an average over four studies. MDLs are for MS/SCAN for Lab #1 and for MS/SIM for Lab #2.

Figure 110. EPA TO-15 method detection limits (MDLs)

Table 18. EPA TO-15 compounds detected by lab samples and PID minimum detection limits (MDLs)

			Alphasense application note AAN 305-06 Detected by Photoionization Detector					**MDL**	**MDL**	**Detected by EPA Method TO-15**		
					Response Factor (RF)	**Response Factor (RF)**	**Response Factor (RF)**	**Typical MDL, 10.6 eV lamp**	**Typical MDL, 10.6 eV lamp**	**Deicing Fluid**	**Hydraulic Fluid**	**Turbine Oil**
Chemical name	**Alternative name**	**Formula**	**CAS no.**	**IE, eV**	**10.0 eV**	**10.6 eV**	**11.7 eV**	**PID-AH2 (ppb)**	**PID-A12 (ppb)**			
Acetaldehyde		C2H4O	75-07-0	10.23	NR	5.5	2.2	25	**480**	**X**	**X**	**X**
Acrolein	Prop-2-enal	C3H4O	107-02-8	10.22	NA	3.2	1.2	20	**400**		**X**	**X**
Butane, n-		C4H10	106-97-8	10.63	NR	40	1.5	230	**4600**			**X**
Butanol, 1-		C4H10O	71-36-3	10.04	25	3.9	1	20	**400**		**X**	**X**
Butanol, 2-		C4H10O	78-92-2	10.10	8	3	1.2					**X**
Butyraldehyde	Butanal	C4H8O	123-72-8	9.86	1.9	1.7	1.2				**X**	**X**
Chlorobutane, 2-		C4H9Cl	78-86-4	10.57	NR	5.8	1					**X**
Chloroethyl methyl ether, 2-	2,2-Dichloroethyl methyl ether	C3H7ClO	627-42-9	10.25	NA	2.6	NA	13	**250**			**X**
Chloromethane		CH3Cl	74-87-3	11.28	NR	NR	0.74					**X**
Decane, n-		C10H22	124-18-5	9.65	4.2	1.2	0.37	5	**100**		**X**	**X**
Dimethyl disulfide	DMDS	C2H6S2	624-92-0	8.46	NA	0.2	NA	1	**23**	**X**		
Dimethylpentane, 2,4-	Dimethylpentane, 2,4-	C7H16	108-08-7	~9.8	NA	1	NA				**X**	
Dipentene	limonene	C10H16	138-86-3	~8.6	0.8	0.9	1	5	**90**		**X**	**X**
Dodecane		C12H24	112-40-3	~8.8	NA	1	NA					**X**
Ethanol	alcohol, ethyl alcohol	C2H6O	64-17-5	10.43	NR	11	3	45	**870**			**X**
Ethyl hexanol, 2-		C8H18O	104-76-7	~9.8	NA	1.5	1					**X**
Eucalyptol	1,8-cineol	C10H18O	470-82-6	~9	NA	0.6	NA					**X**
Formaldehyde	Formaldehyde	CH2O	50-00-0	10.87	NR	NR	0.6					**X**
Hexanoic acid		C6H12O2	142-62-1	10.12	NA	4	NA				**X**	
Hexanol		C6H14O	111-27-3	9.89	7	2	0.66				**X**	
Hexylaldehyde	hexanal	C6H12O	66-25-1	9.72	1.8	1.2	0.54					**X**
Isobutylene	2-Methyl-1-propene	C4H8	115-11-7	9.24	1	1	1	5	**100**		**X**	**X**
Isobutyraldehyde	2-Methylpropanal	C4H8O	78-84-2	9.74	NA	1.2	NA	6	**120**		**X**	**X**
Isooctanol	2-Octanol	C8H18O	26952-21-6	~9.8	NA	1.7	1	9	**170**		**X**	

			Alphasense application note AAN 305-06 Detected by Photoionization Detector					**MDL**	**MDL**	**Detected by EPA Method TO-15**		
					Response Factor (RF)	**Response Factor (RF)**	**Response Factor (RF)**	**Typical MDL, 10.6 eV lamp**	**Typical MDL, 10.6 eV lamp**	**Deicing Fluid**	**Hydraulic Fluid**	**Turbine Oil**
Chemical name	**Alternative name**	**Formula**	**CAS no.**	**IE, eV**	**10.0 eV**	**10.6 eV**	**11.7 eV**	**PID-AH2 (ppb)**	**PID-A12 (ppb)**			
Isopentane	2-Methylbutane	C_5H_{12}	78-78-4	10.32	NR	4	4	30	**600**		**X**	**X**
Methyl ethyl ketone	MEK, Butan-2-one	C_4H_8O	78-93-3	9.51	2	0.96	1.2	4	**80**			**X**
Methyl isobutyl ketone	MIBK, 4-methylpentan-2-one	$C_6H_{12}O$	108-10-1	9.30	1.01	0.9	0.7	4	**80**			**X**
Methylhexan-2-one, 5-	MIAK, methyl isoamyl ketone	$C_7H_{14}O$	110-12-3	9.28	0.91	0.7	0.58	4	**75**			**X**
Nonane		C_9H_{20}	111-84-2	9.72	4.7	1.4	0.4	6	**130**			**X**
Nonene, 1-		C_9H_{18}	124-11-8	~9.4	NA	0.6	NA					**X**
Octamethylcyclotetrasiloxane		$C_6H_{12}O_4Si_4$	556-67-2	~10	NA	0.3	NA				**X**	
Pentanal, Valeraldehyde	Valeraldehyde, pentyl aldehyde	$C_5H_{10}O$	110-62-3	9.74	1.75	1.5	0.7			**X**	**X**	**X**
Pentane		C_5H_{12}	109-66-0	10.35	NR	7	0.7	40	**800**		**X**	
Propane		C_3H_8	74-98-6	11.07	NR	NR	1.8					**X**
Propene	propylene	C_3H_6	115-07-1	9.73	2	1.4	1	7	**140**			**X**
Propiolic acid	2-propynoic acid	$C_3H_2O_2$	471-25-0	10.45	NR	8	NA				**X**	
Propionaldehyde	propanal, propional	C_3H_6O	123-38-6	9.95	NA	1.7	2	8	**169**		**X**	**X**
Trimethylbenzene mixtures	1,2,3-trimethyl-Benzene	C_9H_{12}	25551-13-7	8.41	0.3	0.3	0.3					**X**
Trimethylcyclohexane, 1,2,4-		C_9H_{18}	2234-75-5	9.35	NA	1	NA					X
Undecane		$C_{11}H_{24}$	1120-21-4	9.56	3.1	1.1	0.4	5	100		X	X



Summary Chart- TO 15 Hit List Markers

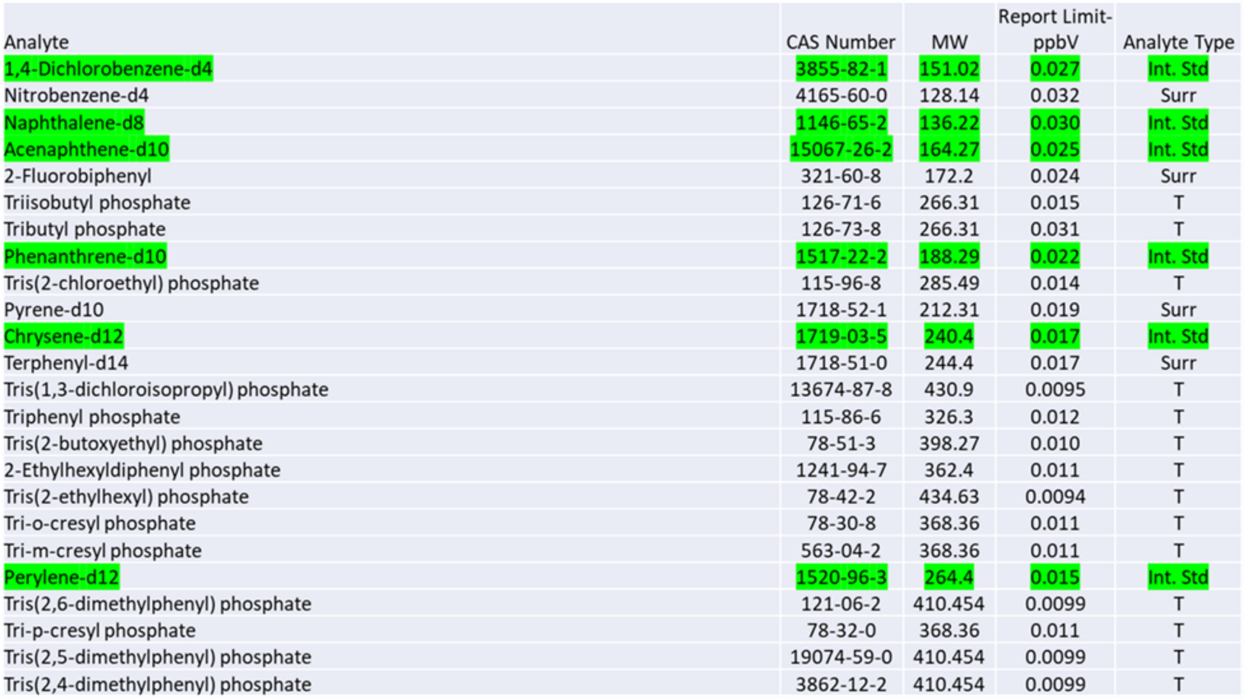
Compound	200 ˚C	Max Bleed
Chloromethane	Mobil 387 (HTS Oil) Eastman 2389 (Type 3 Oil)	Mobil 387 (HTS Oil) Mobil Jet II (Type 4 Std Oil)
2-Butanone	Mobil 387 (HTS Oil)	Mobil 387 (HTS Oil)
MiBK		Mobil 387 (HTS Oil)
Ethanol	Mobil Jet II (Type 4 Std Oil)	Mobil Jet II (Type 4 Std Oil)
Propene	Mobil Jet II (Type 4 Std Oil)	Mobil Jet II (Type 4 Std Oil) HyJet IV-A+

These compounds are ubiquitous, found everywhere

Figure 111. Summary of most prevalent compounds found in study fluid samples

3.2.4 Quartz filters by EPA TO-13A and EPA Method 8270E

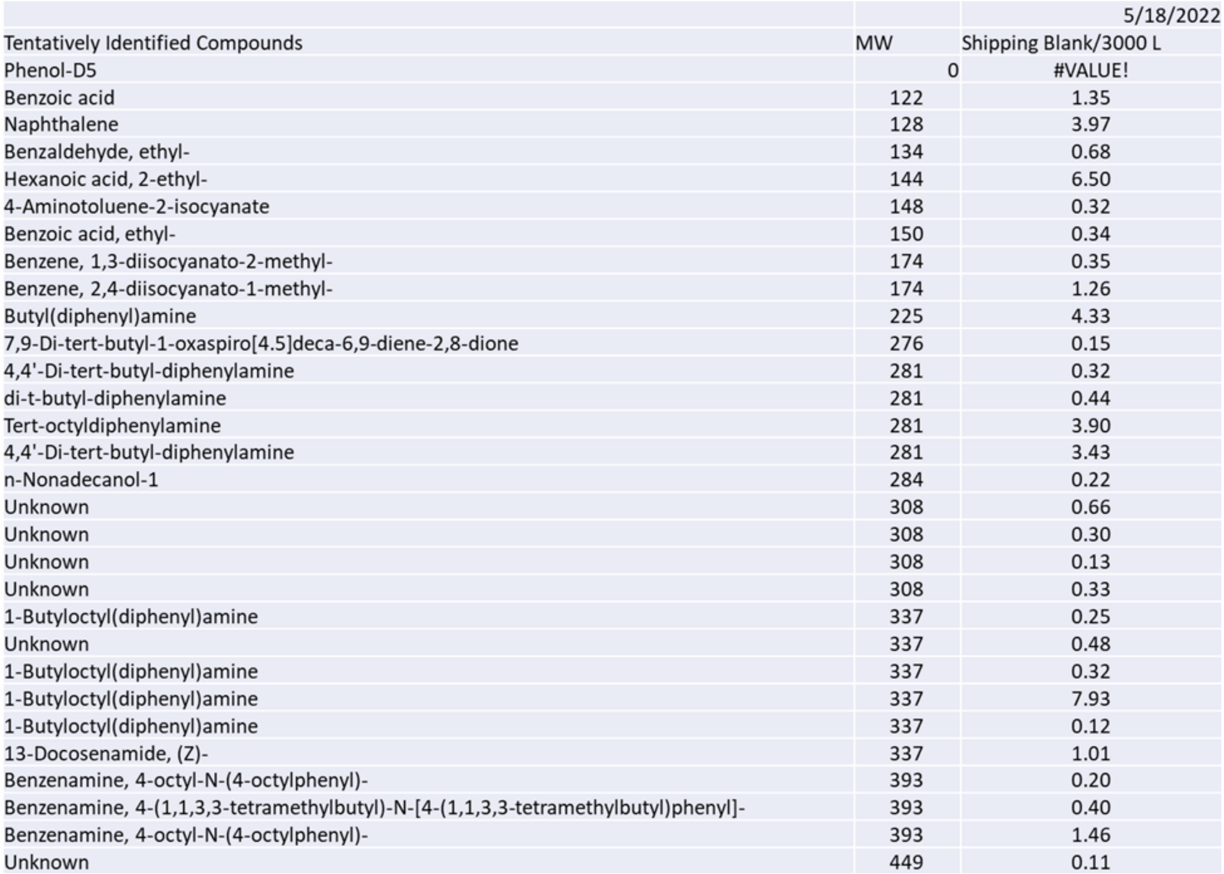
The EPA TO-13 target compound list is presented in Figure 112.



Analyte	CAS Number	MW	Report Limit-ppbV	Analyte Type
1,4-Dichlorobenzene-d4	3855-82-1	151.02	0.027	Int. Std
Nitrobenzene-d4	4165-60-0	128.14	0.032	Surr
Naphthalene-d8	1146-65-2	136.22	0.030	Int. Std
Acenaphthene-d10	15067-26-2	164.27	0.025	Int. Std
2-Fluorobiphenyl	321-60-8	172.2	0.024	Surr
Triisobutyl phosphate	126-71-6	266.31	0.015	T
Tributyl phosphate	126-73-8	266.31	0.031	T
Phenanthrene-d10	1517-22-2	188.29	0.022	Int. Std
Tris(2-chloroethyl) phosphate	115-96-8	285.49	0.014	T
Pyrene-d10	1718-52-1	212.31	0.019	Surr
Chrysene-d12	1719-03-5	240.4	0.017	Int. Std
Terphenyl-d14	1718-51-0	244.4	0.017	Surr
Tris(1,3-dichloroisopropyl) phosphate	13674-87-8	430.9	0.0095	T
Triphenyl phosphate	115-86-6	326.3	0.012	T
Tris(2-butoxyethyl) phosphate	78-51-3	398.27	0.010	T
2-Ethylhexyldiphenyl phosphate	1241-94-7	362.4	0.011	T
Tris(2-ethylhexyl) phosphate	78-42-2	434.63	0.0094	T
Tri-o-cresyl phosphate	78-30-8	368.36	0.011	T
Tri-m-cresyl phosphate	563-04-2	368.36	0.011	T
Perylene-d12	1520-96-3	264.4	0.015	Int. Std
Tris(2,6-dimethylphenyl) phosphate	121-06-2	410.454	0.0099	T
Tri-p-cresyl phosphate	78-32-0	368.36	0.011	T
Tris(2,5-dimethylphenyl) phosphate	19074-59-0	410.454	0.0099	T
Tris(2,4-dimethylphenyl) phosphate	3862-12-2	410.454	0.0099	T

Figure 112. EPA TO-13 target compound list

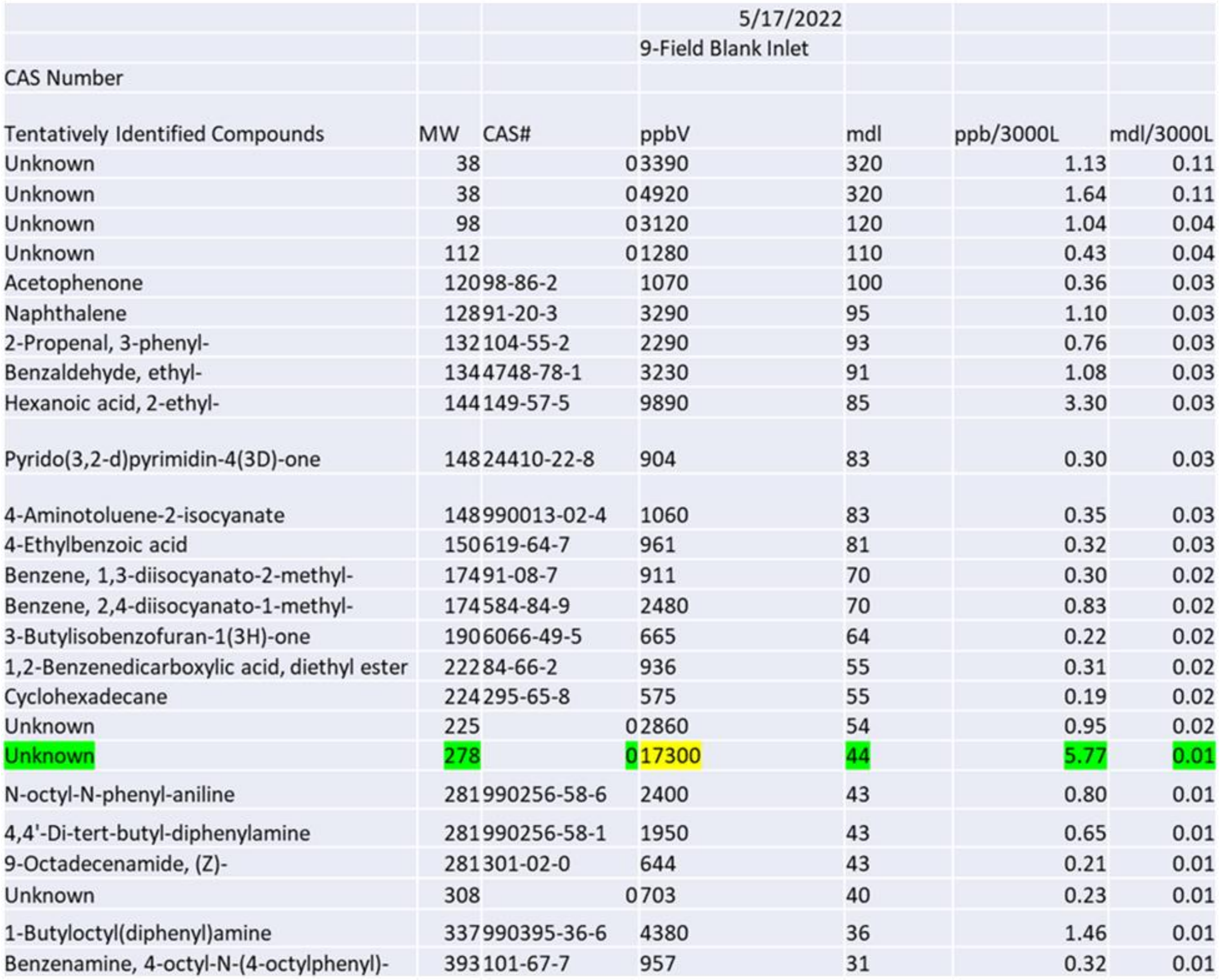
The shipping blank results summary is presented in Figure 113.



		5/18/2022
Tentatively Identified Compounds	MW	Shipping Blank/3000 L
Phenol-D5	0	#VALUE!
Benzoic acid	122	1.35
Naphthalene	128	3.97
Benzaldehyde, ethyl-	134	0.68
Hexanoic acid, 2-ethyl-	144	6.50
4-Aminotoluene-2-isocyanate	148	0.32
Benzoic acid, ethyl-	150	0.34
Benzene, 1,3-diisocyanato-2-methyl-	174	0.35
Benzene, 2,4-diisocyanato-1-methyl-	174	1.26
Butyl(diphenyl)amine	225	4.33
7,9-Di-tert-butyl-1-oxaspiro[4.5]deca-6,9-diene-2,8-dione	276	0.15
4,4'-Di-tert-butyl-diphenylamine	281	0.32
di-t-butyl-diphenylamine	281	0.44
Tert-octyldiphenylamine	281	3.90
4,4'-Di-tert-butyl-diphenylamine	281	3.43
n-Nonadecanol-1	284	0.22
Unknown	308	0.66
Unknown	308	0.30
Unknown	308	0.13
Unknown	308	0.33
1-Butyloctyl(diphenyl)amine	337	0.25
Unknown	337	0.48
1-Butyloctyl(diphenyl)amine	337	0.32
1-Butyloctyl(diphenyl)amine	337	7.93
1-Butyloctyl(diphenyl)amine	337	0.12
13-Docosenamide, (Z)-	337	1.01
Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	0.20
Benzenamine, 4-(1,1,3,3-tetramethylbutyl)-N-[4-(1,1,3,3-tetramethylbutyl)phenyl]-	393	0.40
Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	1.46
Unknown	449	0.11

Figure 113. EPA TO-13 shipping blank results summary

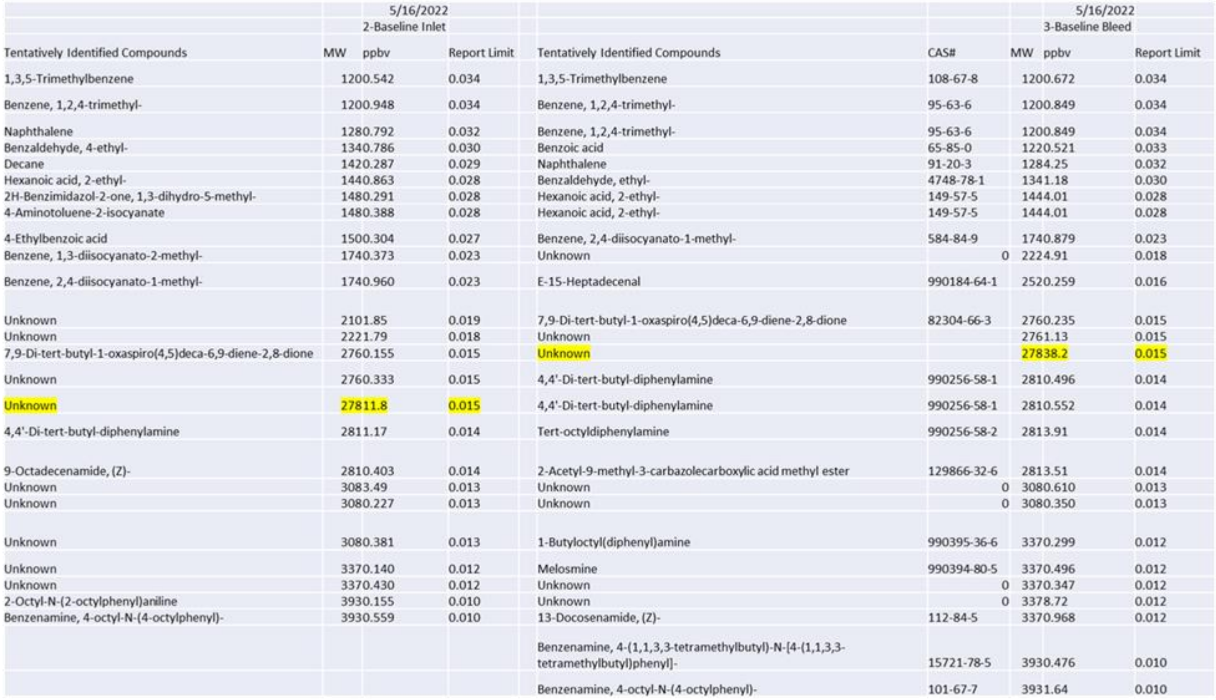
A TO-13 field blank results summary is presented in Figure 114.



			5/17/2022			
			9-Field Blank Inlet			
CAS Number						
Tentatively Identified Compounds	MW	CAS#	ppbV	mdl	ppb/3000L	mdl/3000L
Unknown	38	0	3390	320	1.13	0.11
Unknown	38	0	4920	320	1.64	0.11
Unknown	98	0	3120	120	1.04	0.04
Unknown	112	0	1280	110	0.43	0.04
Acetophenone	120	98-86-2	1070	100	0.36	0.03
Naphthalene	128	91-20-3	3290	95	1.10	0.03
2-Propenal, 3-phenyl-	132	104-55-2	2290	93	0.76	0.03
Benzaldehyde, ethyl-	134	4748-78-1	3230	91	1.08	0.03
Hexanoic acid, 2-ethyl-	144	149-57-5	9890	85	3.30	0.03
Pyrido(3,2-d)pyrimidin-4(3D)-one	148	24410-22-8	904	83	0.30	0.03
4-Aminotoluene-2-isocyanate	148	990013-02-4	1060	83	0.35	0.03
4-Ethylbenzoic acid	150	619-64-7	961	81	0.32	0.03
Benzene, 1,3-diisocyanato-2-methyl-	174	91-08-7	911	70	0.30	0.02
Benzene, 2,4-diisocyanato-1-methyl-	174	584-84-9	2480	70	0.83	0.02
3-Butylisobenzofuran-1(3H)-one	190	6066-49-5	665	64	0.22	0.02
1,2-Benzenedicarboxylic acid, diethyl ester	222	84-66-2	936	55	0.31	0.02
Cyclohexadecane	224	295-65-8	575	55	0.19	0.02
Unknown	225	0	2860	54	0.95	0.02
Unknown	278	0	17300	44	5.77	0.01
N-octyl-N-phenyl-aniline	281	990256-58-6	2400	43	0.80	0.01
4,4'-Di-tert-butyl-diphenylamine	281	990256-58-1	1950	43	0.65	0.01
9-Octadecenamide, (Z)-	281	301-02-0	644	43	0.21	0.01
Unknown	308	0	703	40	0.23	0.01
1-Butyloctyl(diphenyl)amine	337	990395-36-6	4380	36	1.46	0.01
Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	101-67-7	957	31	0.32	0.01

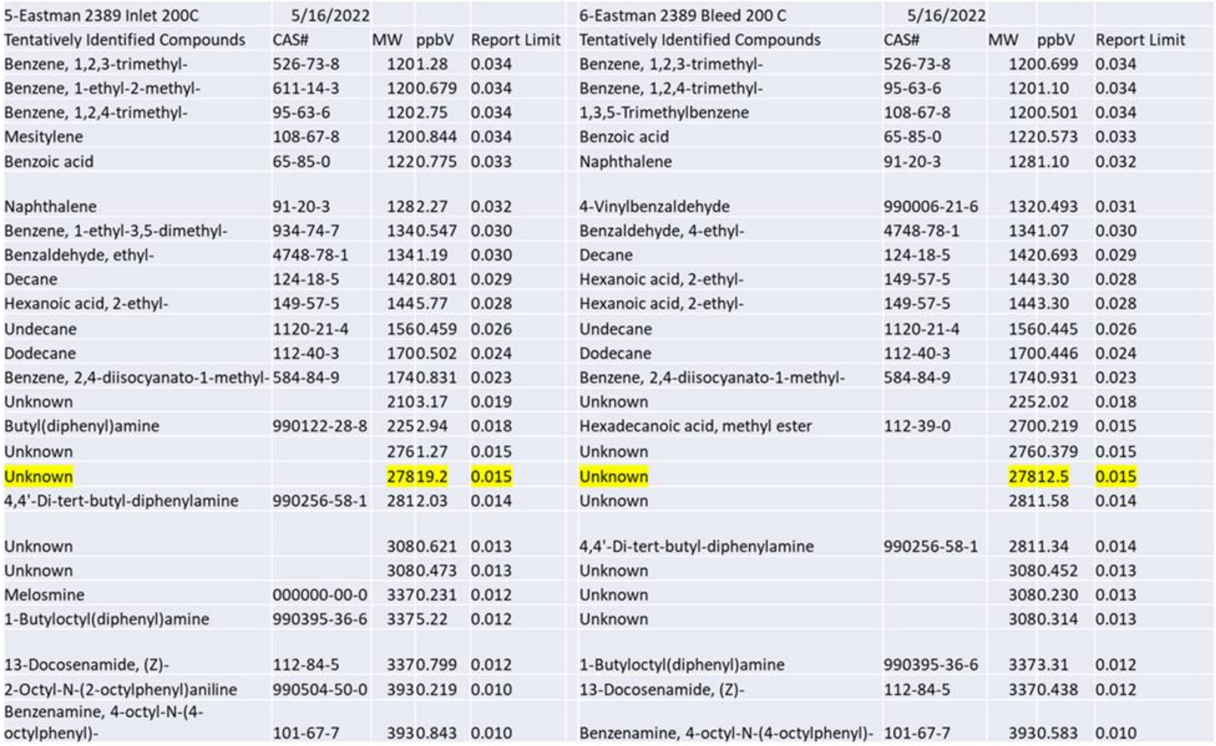
Figure 114. EPA TO-13A field blank results summary

An EPA TO-13A baseline inlet and bleed results summary for Eastman 2389 and Mobil 387 is presented in Figure 115. An EPA TO-13A Eastman 2389 results summary during oil injection is presented in Figure 116.



		5/16/2022					5/16/2022	
		2-Baseline Inlet					3-Baseline Bleed	
Tentatively Identified Compounds	MW	ppbv	Report Limit	Tentatively Identified Compounds	CAS#	MW	ppbv	Report Limit
1,3,5-Trimethylbenzene	120	0.542	0.034	1,3,5-Trimethylbenzene	108-67-8	120	0.672	0.034
Benzene, 1,2,4-trimethyl-	120	0.948	0.034	Benzene, 1,2,4-trimethyl-	95-63-6	120	0.849	0.034
Naphthalene	128	0.792	0.032	Benzene, 1,2,4-trimethyl-	95-63-6	120	0.849	0.034
Benzaldehyde, 4-ethyl-	134	0.786	0.030	Benzoic acid	65-85-0	122	0.521	0.033
Decane	142	0.287	0.029	Naphthalene	91-20-3	128	4.25	0.032
Hexanoic acid, 2-ethyl-	144	0.863	0.028	Benzaldehyde, ethyl-	4748-78-1	134	1.18	0.030
2H-Benzimidazol-2-one, 1,3-dihydro-5-methyl-	148	0.291	0.028	Hexanoic acid, 2-ethyl-	149-57-5	144	4.01	0.028
4-Aminotoluene-2-isocyanate	148	0.388	0.028	Hexanoic acid, 2-ethyl-	149-57-5	144	4.01	0.028
4-Ethylbenzoic acid	150	0.304	0.027	Benzene, 2,4-diisocyanato-1-methyl-	584-84-9	174	0.879	0.023
Benzene, 1,3-diisocyanato-2-methyl-	174	0.373	0.023	Unknown	0	222	4.91	0.018
Benzene, 2,4-diisocyanato-1-methyl-	174	0.960	0.023	E-15-Heptadecenal	990184-64-1	252	0.259	0.016
Unknown	210	1.85	0.019	7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene-2,8-dione	82304-66-3	276	0.235	0.015
Unknown	222	1.79	0.018	Unknown		276	1.13	0.015
7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene-2,8-dione	276	0.155	0.015	Unknown		278	38.2	0.015
Unknown	276	0.333	0.015	4,4'-Di-tert-butyl-diphenylamine	990256-58-1	281	0.496	0.014
Unknown	278	11.8	0.015	4,4'-Di-tert-butyl-diphenylamine	990256-58-1	281	0.552	0.014
4,4'-Di-tert-butyl-diphenylamine	281	1.17	0.014	Tert-octyldiphenylamine	990256-58-2	281	3.91	0.014
9-Octadecenamide, (Z)-	281	0.403	0.014	2-Acetyl-9-methyl-3-carbazolecarboxylic acid methyl ester	129866-32-6	281	3.51	0.014
Unknown	308	3.49	0.013	Unknown	0	308	0.610	0.013
Unknown	308	0.227	0.013	Unknown	0	308	0.350	0.013
Unknown	308	0.381	0.013	1-Butyloctyl(diphenyl)amine	990395-36-6	337	0.299	0.012
Unknown	337	0.140	0.012	Melosmine	990394-80-5	337	0.496	0.012
Unknown	337	0.430	0.012	Unknown	0	337	0.347	0.012
2-Octyl-N-(2-octylphenyl)aniline	393	0.155	0.010	Unknown	0	337	8.72	0.012
Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	0.559	0.010	13-Docosenamide, (Z)-	112-84-5	337	0.968	0.012
				Benzenamine, 4-(1,1,3,3-tetramethylbutyl)-N-[4-(1,1,3,3-tetramethylbutyl)phenyl]-	15721-78-5	393	0.476	0.010
				Benzenamine, 4-octyl-N-(4-octylphenyl)-	101-67-7	393	1.64	0.010

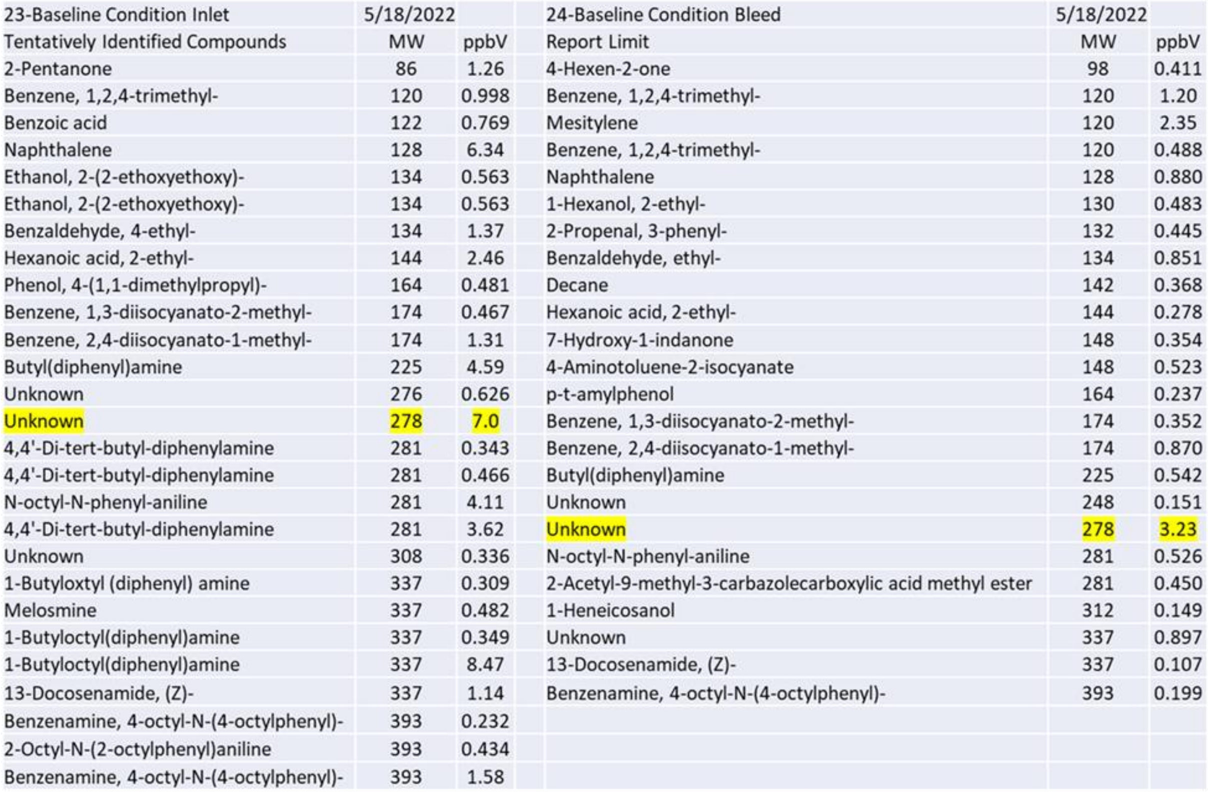
Figure 115. EPA TO-13A baseline inlet and bleed results: Eastman 2389 & Mobil 387



5-Eastman 2389 Inlet 200C	5/16/2022				6-Eastman 2389 Bleed 200 C	5/16/2022			
Tentatively Identified Compounds	CAS#	MW	ppbV	Report Limit	Tentatively Identified Compounds	CAS#	MW	ppbV	Report Limit
Benzene, 1,2,3-trimethyl-	526-73-8	120	1.28	0.034	Benzene, 1,2,3-trimethyl-	526-73-8	120	0.699	0.034
Benzene, 1-ethyl-2-methyl-	611-14-3	120	0.679	0.034	Benzene, 1,2,4-trimethyl-	95-63-6	120	1.10	0.034
Benzene, 1,2,4-trimethyl-	95-63-6	120	2.75	0.034	1,3,5-Trimethylbenzene	108-67-8	120	0.501	0.034
Mesitylene	108-67-8	120	0.844	0.034	Benzoic acid	65-85-0	122	0.573	0.033
Benzoic acid	65-85-0	122	0.775	0.033	Naphthalene	91-20-3	128	1.10	0.032
Naphthalene	91-20-3	128	2.27	0.032	4-Vinylbenzaldehyde	990006-21-6	132	0.493	0.031
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134	0.547	0.030	Benzaldehyde, 4-ethyl-	4748-78-1	134	1.07	0.030
Benzaldehyde, ethyl-	4748-78-1	134	1.19	0.030	Decane	124-18-5	142	0.693	0.029
Decane	124-18-5	142	0.801	0.029	Hexanoic acid, 2-ethyl-	149-57-5	144	3.30	0.028
Hexanoic acid, 2-ethyl-	149-57-5	144	5.77	0.028	Hexanoic acid, 2-ethyl-	149-57-5	144	3.30	0.028
Undecane	1120-21-4	156	0.459	0.026	Undecane	1120-21-4	156	0.445	0.026
Dodecane	112-40-3	170	0.502	0.024	Dodecane	112-40-3	170	0.446	0.024
Benzene, 2,4-diisocyanato-1-methyl-	584-84-9	174	0.831	0.023	Benzene, 2,4-diisocyanato-1-methyl-	584-84-9	174	0.931	0.023
Unknown		210	3.17	0.019	Unknown		225	2.02	0.018
Butyl(diphenyl)amine	990122-28-8	225	2.94	0.018	Hexadecanoic acid, methyl ester	112-39-0	270	0.219	0.015
Unknown		276	1.27	0.015	Unknown		276	0.379	0.015
Unknown		278	19.2	0.015	Unknown		278	12.5	0.015
4,4'-Di-tert-butyl-diphenylamine	990256-58-1	281	2.03	0.014	Unknown		281	1.58	0.014
Unknown		308	0.621	0.013	4,4'-Di-tert-butyl-diphenylamine	990256-58-1	281	1.34	0.014
Unknown		308	0.473	0.013	Unknown		308	0.452	0.013
Melosmine	000000-00-0	337	0.231	0.012	Unknown		308	0.230	0.013
1-Butyloctyl(diphenyl)amine	990395-36-6	337	5.22	0.012	Unknown		308	0.314	0.013
13-Docosenamide, (Z)-	112-84-5	337	0.799	0.012	1-Butyloctyl(diphenyl)amine	990395-36-6	337	3.31	0.012
2-Octyl-N-(2-octylphenyl)aniline	990504-50-0	393	0.219	0.010	13-Docosenamide, (Z)-	112-84-5	337	0.438	0.012
Benzenamine, 4-octyl-N-(4-octylphenyl)-	101-67-7	393	0.843	0.010	Benzenamine, 4-octyl-N-(4-octylphenyl)-	101-67-7	393	0.583	0.010

Figure 116. EPA TO-13A Eastman 2389 results summary

EPA TO-13A baseline inlet and bleed air results for HyJet IV-A and Skydrol PE-5 are presented in Figure 117.



23-Baseline Condition Inlet	5/18/2022			24-Baseline Condition Bleed	5/18/2022	
Tentatively Identified Compounds	MW	ppbV		Report Limit	MW	ppbV
2-Pentanone	86	1.26		4-Hexen-2-one	98	0.411
Benzene, 1,2,4-trimethyl-	120	0.998		Benzene, 1,2,4-trimethyl-	120	1.20
Benzoic acid	122	0.769		Mesitylene	120	2.35
Naphthalene	128	6.34		Benzene, 1,2,4-trimethyl-	120	0.488
Ethanol, 2-(2-ethoxyethoxy)-	134	0.563		Naphthalene	128	0.880
Ethanol, 2-(2-ethoxyethoxy)-	134	0.563		1-Hexanol, 2-ethyl-	130	0.483
Benzaldehyde, 4-ethyl-	134	1.37		2-Propenal, 3-phenyl-	132	0.445
Hexanoic acid, 2-ethyl-	144	2.46		Benzaldehyde, ethyl-	134	0.851
Phenol, 4-(1,1-dimethylpropyl)-	164	0.481		Decane	142	0.368
Benzene, 1,3-diisocyanato-2-methyl-	174	0.467		Hexanoic acid, 2-ethyl-	144	0.278
Benzene, 2,4-diisocyanato-1-methyl-	174	1.31		7-Hydroxy-1-indanone	148	0.354
Butyl(diphenyl)amine	225	4.59		4-Aminotoluene-2-isocyanate	148	0.523
Unknown	276	0.626		p-t-amylphenol	164	0.237
Unknown	278	7.0		Benzene, 1,3-diisocyanato-2-methyl-	174	0.352
4,4'-Di-tert-butyl-diphenylamine	281	0.343		Benzene, 2,4-diisocyanato-1-methyl-	174	0.870
4,4'-Di-tert-butyl-diphenylamine	281	0.466		Butyl(diphenyl)amine	225	0.542
N-octyl-N-phenyl-aniline	281	4.11		Unknown	248	0.151
4,4'-Di-tert-butyl-diphenylamine	281	3.62		Unknown	278	3.23
Unknown	308	0.336		N-octyl-N-phenyl-aniline	281	0.526
1-Butyloxtyl (diphenyl) amine	337	0.309		2-Acetyl-9-methyl-3-carbazolecarboxylic acid methyl ester	281	0.450
Melosmine	337	0.482		1-Heneicosanol	312	0.149
1-Butyloctyl(diphenyl)amine	337	0.349		Unknown	337	0.897
1-Butyloctyl(diphenyl)amine	337	8.47		13-Docosenamide, (Z)-	337	0.107
13-Docosenamide, (Z)-	337	1.14		Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	0.199
Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	0.232				
2-Octyl-N-(2-octylphenyl)aniline	393	0.434				
Benzenamine, 4-octyl-N-(4-octylphenyl)-	393	1.58				

Figure 117. Summary of EPA TO-13A baseline inlet & bleed air contaminants detected for HyJet IV-A and Skydrol PE-5

Results from the quartz filters that were in the sample train ahead of the PUF/XAD cartridges are found in RJ Lee Laboratory Report W205178. This report is included in the supporting dataset for this report. The quartz filters were also analyzed by EPA method TO-13A and EPA Method 8270E (EPA, 2014). KSU provided RJ Lee Laboratory the list of organophosphate compounds that were reported in the EASA Study (Schuchardt, 2014).

RJ Lee Laboratory determined concentrations of the mono- and di-ortho-tricresyl phosphates, if they were present in samples, from the calibration curve of tri-ortho-cresyl-phosphate. The lab reported that various isomers of the tri-xylyl phosphates were quantified against a calibration curve that was an average of the total ion current response of the tris(2,4-dimethylphenyl)-, tris (2,5-dimethylphenyl, and tris(2,6-dimethylphenyl) phosphate calibration curves. They noted the nominal masses of tri-x-cresyl phosphate and tris (y, y-dimethylphenyl) phosphate isomers are 368 and 410, respectively. The lab concluded that for project W205178, there were five potential isomers of TCP and three potential isomers of TXP. The RJ Lee Laboratory also found an additional group of phosphate compounds in some samples with a nominal mass of 452 amu, which consisted of tris (y, y-propyl phenyl) and tris(y,y-isopropylphenyl) phosphate isomers. They quantified these results using the average total ion current calibration curve for tris (y, y-dimethylphenyl) phosphates.

The RJ Lee Laboratory used a naming convention in the reports ‘TPP-x’[Tris(y, y-Propyl phenyl) Phosphate or Tris(y,y-isoPropylphenyl) Phosphate] where ‘x’ is a number representing one of the six (6) isomers observed in the samples.

The lab also reported that other organo-phosphates (most notably, dibutylphenyl phosphoric acid and butyl-diphenyl phosphoric acid) were observed in the TIC reports of some samples that are not specified in Appendix G, EASA OPC Target List (Schuchardt, 2014). The concentrations of the additional phosphates were estimated in the same manner as other reported TICS. RJ Lee Laboratory separated TICS into two classifications, a) those with non-calibrated isomers of targe organo-phosphate compounds, and b) non-target TICS that are not part of the calibrated list of compounds.

A summary of Tri-isobutyl phosphate detected in quartz filters, and in the PUF cartridges below the quartz filters is presented in Table 19. The concentrations of the analyte were greater in the quartz filter than in the PUF cartridge that followed the filter. A summary of tributyl phosphate measured in samples is presented in Table 20. Tri-isobutyl phosphate and tributyl phosphate were identified in almost all blanks and samples. Quantities present in blanks are reported as mass per sample since there was no airflow through the sample media. A summary of triphenyl phosphate measured in samples is presented in Table 21. Triphenyl phosphate was seldom detected in the engine inlet samples and not as frequently detected as tri-isobutyl phosphate and tributyl phosphate.

Two tentatively identified tricresyl phosphates isomers that were only present in turbine oils and an engine clean-out sample are presented in Table 22. These TICS were present in all three of the oil types tested. They were not present in any of the field blanks, engine inlet samples, or hydraulic fluid samples. Results for the five organophosphates detected in quartz filters and PUF cartridges are listed in units of ppbV, ug/m3, and ug/sample. Results for quartz filters are presented in the tables adjacent to the corresponding PUF cartridge sample, if one was collected for the sample.

Table 19. Tri-isobutyl phosphate measured in quartz filters and PUF cartridges

Triisobutyl phosphate	**CAS Number**	**126-71-6**	**MW = 266.31**			
	Quartz	**PUF**	**Quartz**	**PUF**	**Quartz**	**PUF**
Client Sample ID	**Result-ppbV**	**Result-ppbV**	**Result ug/m^3**	**Result ug/m^3**	**Result ug/sample**	**Result ug/sample**
8-Field Blank					0.000710	< 0.00050
21-Field Blank					0.000630	
30-Field Blank N/A					0.000700	
30-Field Blank N/A					0.00688	
2-Baseline 2389 200˚C Inlet	0.0226	0.015	0.740	< 0.50	2.22	< 1.5
3-Baseline 2389 200˚C Bleed	0.0281	< 0.015	0.920	< 0.50	2.76	< 1.5
4-Eastman™ 2389 200˚C Inlet	0.0232	< 0.015	0.760	< 0.50	2.28	< 1.5
5-Eastman™ 2389 200˚C Bleed	0.0297	< 0.015	0.970	< 0.50	2.28	< 1.5
6-Eastman™ 2389 260˚C Inlet	0.0236	< 0.015	0.770	< 0.50	2.91	< 1.5
7-Eastman™ 2389 260˚C Bleed	0.0254	< 0.015	0.830	< 0.50	2.31	< 1.5
10-Baseline Mobil™ Jet™ II 200˚C Inlet	0.0196	< 0.015	0.640	< 0.50	1.92	< 1.5
11-Baseline Mobil™ Jet™ II 200˚C Bleed	0.0232	< 0.015	0.760	< 0.50	2.28	< 1.5
13-Mobil™ Jet™ II 200˚C Bleed	0.0211	< 0.015	0.690	< 0.50	2.07	< 1.5
15-Mobil™ Jet™ II 250˚C Bleed	0.0208	< 0.015	0.680	< 0.50	2.04	< 1.5
42-Replicate Baseline 200˚C Mobil™ Jet™ II Inlet	0.0303		0.990		2.97	
43-Replicate Baseline 200˚C Mobil™ Jet™ II Bleed	0.344		11.3		33.8	
44-Replicate Mobil™ Jet™ II 200˚C Inlet	0.0441		1.44		4.32	
45 Replicate Mobil™ Jet™ II 200˚C Bleed	0.116		3.79		11.4	
46 Replicate Mobil™ Jet™ II 250˚C Inlet	0.0471		1.54		4.62	
47-Replicate Mobil™ Jet™ II 250˚C Bleed	0.102		3.34		10.0	
16-200˚C Mobil-387 Baseline Inlet	0.0187	< 0.015	0.610	< 0.50	1.83	< 1.5
17-200˚C Mobil-387 Baseline Bleed	0.0232	< 0.015	0.760	< 0.50	2.28	< 1.5
17a-Mobil-387 200˚C Inlet	0.0184		0.600		1.80	
18-Mobil-387 200˚C Bleed	0.0202	< 0.015	0.660	< 0.50	1.98	< 1.5
19-Mobil-387 250˚C Inlet	0.0190		0.620		1.86	
20-Mobil-387 250˚C Bleed	0.0196	< 0.015	0.640	< 0.50	1.92	< 1.5
1a-Baseline PE-5 200˚C Inlet	0.0190	< 0.015	0.620	< 0.50	1.86	< 1.5
1b-Baseline PE-5 200˚C Bleed	0.0211	< 0.015	0.690	< 0.50	2.07	1.41
26-PE-5 200˚C Inlet	0.0392		1.28		3.84	
27-PE-5 200˚C Bleed	3.56		116		349	
28-PE-5 250˚C Inlet	0.168		5.48		16.4	

Triisobutyl phosphate	**CAS Number**	**126-71-6**	**MW = 266.31**			
	Quartz	**PUF**	**Quartz**	**PUF**	**Quartz**	**PUF**
Client Sample ID	**Result-ppbV**	**Result-ppbV**	**Result ug/m^3**	**Result ug/m^3**	**Result ug/sample**	**Result ug/sample**
29-PE-5 250˚C Bleed	1.80	12.3	58.9	403	177	1210
31-Baseline 200˚C HyJet™ IV-A Inlet	0.0324		1.06		3.18	
32-Baseline200˚C HyJet™ IV-A Bleed	0.499		16.3		48.9	
33 HyJet™ IV-A 200˚C Inlet	0.0575		1.88		5.64	
34 HyJet™ IV-A 200˚C Bleed	0.217		7.08		21.2	
35-HyJet™ IV-A 250˚C Inlet	0.0324		1.06		3.18	
36-HyJet™ IV-A 250˚C Bleed	0.0774	1.09	2.53	35.7	7.59	107
38-Baseline Deice 200˚C Inlet	0.0236		0.770		2.31	
39-Baseline Deice 200˚C Bleed	0.450		14.7		44.1	
40—Deicing Type I 200˚C Inlet	0.0245		0.800		2.40	
41-Deicing Type I 200˚C Bleed	0.523		17.1		51.3	
48-Cleanout Inlet	0.0792		2.59		7.77	
49-Cleanout Bleed	0.107		3.51		10.5	
50-Afternoon Test Run (4:12pm) Bleed	0.120		3.91		11.7	
51-Diesel Forklift Exhaust Ingestion Bleed	0.154		5.04		15.1	
52-2004 Chevy 1500 Exhaust Ingestion Bleed	0.126		4.13		12.4	

Table 20. Tributyl phosphate measured in quartz filters and PUF cartridges

Tributyl phosphate	**CAS Number**	**126-73-8**		**MW = 266.31**		
	Quartz	**PUF**	**Quartz**	**PUF**	**Quartz**	**PUF**
Client Sample ID	**Result-ppbV**	**Result-ppbV**	**Result ug/m^3**	**Result ug/m^3**	**Result ug/sample**	**Result ug/sample**
Shipping Blank						0.00113
21-Field Blank						0.00125
8-Field Blank					0.00186	< 0.0010
21-Field Blank					0.00342	
2-Baseline 2389 200˚C Inlet	0.127	0.031	4.14	< 1.0	12.4	< 3.0
3-Baseline 2389 200˚C Bleed	0.267	< 0.031	8.74	< 1.0	26.2	< 3.0
4-Eastman™ 2389 200˚C Inlet	0.0642	< 0.031	2.10	< 1.0	6.30	< 3.0
5-Eastman™ 2389 200˚C Bleed	0.263	< 0.031	8.59	< 1.0	6.30	< 3.0
6-Eastman™ 2389 260˚C Inlet	0.0569	< 0.031	1.86	< 1.0	25.8	< 3.0
7-Eastman™ 2389 260˚C Bleed	0.240	< 0.031	7.84	< 1.0	5.58	< 3.0
10-Baseline Condition Inlet	0.0434	< 0.031	1.42	< 1.0	4.26	< 3.0
11-Baseline Mobil™ Jet™ II 200˚C Bleed	0.197	< 0.031	6.43	< 1.0	19.3	< 3.0
26-PE-5 200˚C Inlet	0.148		4.85		14.6	
27-PE-5 200˚C Bleed	4.39		143		430	
15-Mobil™ Jet™ II 250˚C Bleed	0.169	< 0.031	5.51	< 1.0	16.5	< 3.0
42-Replicate Baseline 200˚C Mobil™ Jet™ II Inlet	0.533		17.4		52.3	
43-Replicate Baseline 200˚C Mobil™ Jet™ II Bleed	**9.82**		**321**		**963**	
44-Repliucate Mobil™ Jet™ II 200˚C Inlet	3.05		99.7		299	
45 Replicate Mobil™ Jet™ II 200˚C Bleed	5.10		167		500	
46 Replicate Mobil™ Jet™ II 250˚C Inlet	3.27		107		321	
47-ReplicateMobil™ Jet™ II 250˚C Bleed	4.06		133		398	
16-200˚C Mobil-387 Baseline Inlet	0.0899	< 0.031	2.94	< 1.0	8.82	< 3.0
17-200˚C Mobil-387 Baseline Bleed	0.289	< 0.031	9.46	< 1.0	28.4	< 3.0
17a-Mobil-387 200˚C Inlet	0.0976		3.19		9.57	
18-Mobil-387 200˚C Bleed	0.141	< 0.031	4.62	< 1.0	13.9	< 3.0
19-Mobil-387 250˚C Inlet	0.158		5.16		15.5	
20-Mobil-387 250˚C Bleed	0.132	< 0.031	4.33	< 1.0	13.0	< 3.0
1a-Baseline PE-5 200˚C Inlet	0.0581	< 0.031	1.90	< 1.0	5.70	< 3.0
1b-Baseline PE-5 200˚C Bleed	0.155	0.0566	5.07	1.85	15.2	5.55

Tributyl phosphate	**CAS Number**	**126-73-8**		**MW = 266.31**		
	Quartz	**PUF**	**Quartz**	**PUF**	**Quartz**	**PUF**
Client Sample ID	**Result-ppbV**	**Result-ppbV**	**Result ug/m^3**	**Result ug/m^3**	**Result ug/sample**	**Result ug/sample**
28-PE-5 250˚C Inlet	1.86		60.8		182	
29-PE-5 250˚C Bleed	12.1	19.0	395	621	1190	1860
31-Baseline 200˚C HyJet™ IV-A Inlet	0.826		27.0		81.0	
32-Baseline200˚C HyJet™ IV-A Bleed	10.9		355		1070	
33 HyJet™ IV-A 200˚C Inlet	1.39		45.5		136	
34 HyJet™ IV-A 200˚C Bleed	12.2		399		1200	
35-HyJet™ IV-A 250˚C Inlet	2.04		66.7		200	
36-HyJet™ IV-A 250˚C Bleed	9.73	61.1	318	2000	954	5990
38-Baseline Deice 200˚C Inlet	1.23		40.1		120	
39-Baseline Deice 200˚C Bleed	11.0		361		1080	
40—Deicing Type I 200˚C Inlet	0.838		27.4		82.2	
41-Deicing Type I 200˚C Bleed	12.2		398		1200	
48-Cleanout Inlet	5.11		167		501	
49-Cleanout Bleed	6.80		222		667	
50-Afternoon Test Run (4:12pm) Bleed	4.13		135		405	
51-Diesel Forklift Exhaust Ingestion Bleed	5.42		177		531	
52-2004 Chevy 1500 Exhaust Ingestion Bleed	3.14		103		308	

Table 21. Triphenyl phosphate measured in quartz filters and PUF cartridges

Triphenyl phosphate	**CAS Number**	**115-86-6**	**MW = 326.3**			
	Quartz	**PUF**	**Quartz**	**PUF**	**Quartz**	**PUF**
Client Sample ID	**Result- ppbV**	**Result- ppbV**	**Result ug/m^3**	**Result ug/m^3**	**Result ug/sample**	**Result ug/sample**
45 Replicate Mobil™ Jet™ II 200C Bleed	0.163		6.53		19.6	
46 Replicate Mobil™ Jet™ II 250C Inlet	0.0442		1.77		5.31	
47-ReplicateMobil™ Jet™ II 250C Bleed	0.188		7.51		22.5	
48-Cleanout Inlet	0.0592		2.37		7.11	
49-Cleanout Bleed	0.176		7.03		21.1	
50-Afternoon Test Run (4:12pm) Bleed	0.765		30.7		92.0	
51-Diesel Forklift Exhaust Ingestion Bleed	0.0492		1.97		5.91	
13-Mobil™ Jet™ II 200˚C Bleed	0.107	< 0.011	4.85	< 0.50	14.6	< 1.5
15-Mobil™ Jet™ II 250˚C Bleed	0.163	< 0.011	7.38	< 0.50	22.1	< 1.5
45 Replicate Mobil™ Jet™ II 200˚C Bleed	0.126		5.70		17.1	
47-Mobil™ Jet™ II 250˚C Bleed	0.186		8.40		25.2	
18-Mobil-387 200˚C Bleed	0.0579	< 0.011	2.62	< 0.50	7.86	< 1.5
20-Mobil-387 250˚C Bleed	0.164	< 0.011	7.42	< 0.50	22.3	< 1.5
49-Cleanout Bleed	0.108		4.89		14.7	
50-Afternoon Test Run (4:12pm) Bleed	0.459		20.8		62.3	
13-Mobil™ Jet™ II 200˚C Bleed	0.113	< 0.011	5.09	< 0.50	15.3	< 1.5
15-Mobil™ Jet™ II 250˚C Bleed	0.176	< 0.011	7.94	< 0.50	23.8	< 1.5
45 Replicate Mobil™ Jet™ II 200˚C Bleed	0.138		6.23		18.7	
47-Mobil™ Jet™ II 250C Bleed	0.211		9.52		28.6	
18-Mobil-387 200˚C Bleed	0.0652	< 0.011	2.95	< 0.50	8.85	< 1.5
20-Mobil-387 250˚C Bleed	0.151	< 0.011	6.84	< 0.50	20.5	< 1.5
49-Cleanout Bleed	0.0966		4.37		13.1	
50-Afternoon Test Run (4:12pm) Bleed	0.403		18.2		54.6	

Table 22. Tentatively identified TCP isomers measured in quartz filters and PUF cartridges

Tentatively Identified Tricresyl phosphate isomers in Turbine Oils				**MW = 368.36**			
TCP-4 and TCP-5		**Quartz**	**PUF**	**Quartz**	**PUF**	**Quartz**	**PUF**
Client Sample ID		**Result-ppbV**	**Result-ppbV**	**Result ug/m^3**	**Result ug/m^3**	**Result ug/sample**	**Result ug/sample**
6-Eastman™ 2389 260˚C Inlet	TCP-4						
7-Eastman™ 2389 260˚C Bleed	TCP-4	0.0638	< 0.011	2.89	< 0.50	2.49	< 1.5
13-Mobil™ Jet™ II 200˚C Bleed	TCP-4	0.237	< 0.011	10.7	< 0.50	32.1	< 1.5
15-Mobil™ Jet™ II 250˚C Bleed	TCP-4	0.349	< 0.011	15.8	< 0.50	47.4	< 1.5
45 Replicate Mobil™ Jet™ II 200˚C Bleed	TCP-4	0.305		13.8		41.4	
47-ReplicateMobil™ Jet™ II 250˚C Bleed	TCP-4	0.413		18.7		56.1	
18-Mobil-387 200˚C Bleed	TCP-4	0.132	< 0.011	5.98	< 0.50	18.0	< 1.5
20-Mobil-387 250˚C Bleed	TCP-4	0.348	< 0.011	15.7	< 0.50	47.2	< 1.5
49-Cleanout Bleed	TCP-4	0.218		9.87		29.6	
50-Afternoon Test Run (4:12pm) Bleed	TCP-4	0.868		39.2		118	
6-Eastman™ 2389 260˚C Inlet	TCP-5						
7-Eastman™ 2389 260˚C Bleed	TCP-5	0.110	< 0.011	4.97	< 0.50	23.5	< 3.0
13-Mobil™ Jet™ II 200˚C Bleed	TCP-5	0.279	< 0.011	12.6	< 0.50	37.8	< 1.5
15-Mobil™ Jet™ II 250˚C Bleed	TCP-5	0.423	< 0.011	19.1	< 0.50	57.3	< 1.5
45 Replicate Mobil™ Jet™ II 200˚C Bleed	TCP-5	0.323		14.6		43.7	
47-ReplicateMobil™ Jet™ II 250˚C Bleed	TCP-5	0.462		20.9		62.6	
18-Mobil-387 200˚C Bleed	TCP-5	0.140	< 0.011	6.32	< 0.50	18.9	< 1.5
20-Mobil-387 250˚C Bleed	TCP-5	0.355	< 0.011	16.1	< 0.50	48.2	< 1.5
49-Cleanout Bleed	TCP-5	0.0784		3.54		10.6	
50-Afternoon Test Run (4:12pm) Bleed	TCP-5	0.957		43.3		130	

3.2.5 Volatile organic compounds (VOCs) sorbent tube sampling method EPA TO-17

The EPA TO-17 samples consisted of 45 Tenax ® tubes that were analyzed by RJ Lee Laboratories (EPA, 1999). The TO-17 data are found in Report Number W205179, located in the supporting dataset for this report. The TO-17 method is most suited for VOCs that are less volatile than ethane and with sufficient stability for conventional GC methods. A summary of total mass for the EPA TO-17 Target Compounds and TO-17 TICS is presented in Table 23. The total mass of TICS exceeded the total mass of Target Compounds in only one sample. Deicing Fluid and Hyjet IV-A+ each had a bleed TIC sample that exceeded 100 ug/m^3. The data for field blank and shipping blanks are presented in the summary as ng/tube for the shipping blanks and field blanks. A summary of the EPA TO-17 target compounds and report limits is presented in Table 24 through Table 39.

- Table 24. EPA TO-17 Target Compound Summary May16, 2022 Blanks & Baseline, MW 41-142
- Table 25. EPA TO-17 Target Compound Summary (May16, 2022 Eastman 2389, MW 142-266Mobil Jet Oil 387-1)
- Table 26. EPA TO-17 Target Compound Summary (May16, 2022 Eastman 2389, MW 41-142Mobil Jet Oil 387)
- Table 27. EPA TO-17 Target Compound Summary (May16, 2022 Eastman 2389, MW 142-2664)
- Table 28. EPA TO-17 Target Compound Summary (May17, 2022, Mobil Jet II, MW 41-142)
- Table 29. EPA TO-17 Target Compound Summary (May17, 2022, Mobil Jet II, MW 142-266)
- Table 30. EPA TO-17 Target Compound Summary (May17, 2022, Mobil Jet 387, MW 41-142)
- Table 31. EPA TO-17 Target Compound Summary (May17, 2022, Mobil Jet 387, MW 142-266)
- Table 32. EPA TO-17 Target Compound Summary (May18, 2022, Skydrol PE-5, MW 41-142)
- Table 33. EPA TO-17 Target Compound Summary (May18, 2022, Skydrol PE-5, MW 142-266)

- Table 34. EPA TO-17 Target Compound Summary (May18, 2022, Hy-Jet IV-A+, MW 41-142)
- Table 35. EPA TO-17 Target Compound Summary (May18, 2022, Hy-Jet IV-A+, MW 142-266)
- Table 36. EPA TO-17 Target Compound Summary (May19, 2022, Type 1 Deicing Fluid, MW 41-142)
- Table 37. EPA TO-17 Target Compound Summary (May19, 2022, Type 1 Deicing Fluid, MW 142-266)
- Table 38. EPA TO-17 Target Compound Summary (May19, 2022, Repeat Mobil Jet II, MW 41-142)
- Table 39. EPA TO-17 Target Compound Summary (May19, 2022, Repeat Mobil Jet II, MW 142-266)

Sample #463644 appeared to be an outlier for Hexane, as 42.1 ppbV was reported on this 200 ˚C bleed sample for Skydrol PE-5. A number of other inlet and bleed samples appeared to have levels of exhaust type alkenes and alkanes present in quantities greater than 1 ppbV.

Table 23. Total Mass of TO-17 Target Compounds and TO-17 TICS

Test Condition	Time (start)	Engine Bleed Temp [°C]	Sample No	Total EPA TO-17 (ug/cm^3)	Total EPA TO-17TIC (ug/cm^3)	Sample No	Total EPA TO-17(ug/cm^3)	Total EPA TO-17TIC (ug/cm^3)
Monday 05/16/2022			Inlet			Bleed		
Field blank	17:15	N/A	463638					
Shipping blank	N/A	N/A	463641					
Baseline	14:50	200	A035217	8.17	27.78	A035205	6.25	31.05
Eastman 2389 3cst	16:50	200	463636	7.63	1.98	463637	5.95	28.81
Eastman 2389 3cst	18:50	260	A035254	16.02	30.62	463647	8.21	26.62
Tuesday 05/17/2022			Inlet			Bleed		
Baseline	8:50	200	463634	11.62	33.98	463631	3.61	15.43
Mobil Jet II	10:20	200	N/A	3.29	22.17	463643	3.54	31.55
Mobil Jet II	11:57	250	463624	5.03	25.49	463623	7.85	31.96
Baseline	15:18	200	463648	7.85	31.96	463639	6.02	28.70
Mobil 387	16:50	200	463626	7.63	35.71	463633	4.26	27.00
Mobil 387	18:20	250	463625	2.35	27.49	463646	2.70	19.73
Field Blank	17:20	N/A	463622					
Wednesday 05/18/2022			Inlet			Bleed		
Baseline	8:30	200	463642	3.89	15.38	463635	4.16	16.87
PE-5	9:55	200	A035183	1.14	13.80	463644	22.15	26.51
PE-5	11:47	250	463650	0.71	13.56	A034773	2.30	23.07
Baseline	14:32	200	A035167	1.16	19.93	A035270	1.02	38.26
Hyjet IV-A	16:27	200	Y59084	4.52	18.98	Y59070	4.54	124.13
Hyjet IV-A	17:55	250	673918	2.04	17.90	673917	3.18	44.23
Field Blank	17:00	N/A	673930					
Shipping Blank	16:30	N/A	673925					
Thursday 05/19/2022			Inlet			Bleed		
Baseline	8:05	200	673912	3.41	12.87	673914	4.21	32.90
Deicing Type1	8:05	200	673929	1.55	11.60	673923	1.90	116.99
Field Blank	11:22	N/A	673927			N/A		
Baseline	12:19	200	673919	1.53	19.38	673928	1.18	41.97
Mobil Jet II	14:00	200	673915	2.07	22.12	673916	2.51	38.37
Mobil Jet II	15:46	250	673922	1.86	20.52	673926	2.12	29.86

Table 24. EPA TO-17 Target Compound Summary May16, 2022 Blanks & Baseline, MW 41-142

			Monday 5/16/2022, 17:15				Monday 5/16/2022, 14:50				Monday 5/16/2022, 14:50			
EPA Method TO-17 - Tenax			Sample # 463638		Sample # 463641		Sample # A035217				Sample # A035205			
Contaminant			n/a		n/a		Baseline				Baseline			
Bleed Temperature °C			n/a		n/a		200 °C				200 °C			
Sample Location			Field Blank		Ship Blank		Inlet				Bleed			
Analyte	CAS Number	MW	Result ng/tube	Report Limit ng/tube	Result ng/tube	Report Limit ng/tube	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
Acetonitrile	75-05-8	41.00	2.39	0.84			2.87	0.2	1.71	0.12				
Methyl isocyanide	593-75-9	41.00												
Formic acid	64-18-6	46.00												
2-Propenal	107-02-8	56.00												
Acetone	67-64-1	58.00	3.19	1.2	1.83	1.2					2.22	0.37	0.934	0.16
Isopropyl Alcohol	67-63-0	60.00												
1,4-Pentadiene	591-93-5	68.00												
Butanal	123-72-8	72.00												
3-Buten-2-one	78-94-4	70.00												
Cyclopentane	287-92-3	70.00												
Butane, 2-methyl-	78-78-4	72.00	3.89	1.5										
Pentane	109-66-0	72.00												
1-Butanol	71-36-3	74.00	3.79	1.5			7.18	0.36	2.37	0.12	8.57	0.47	2.83	0.16
2-Propanone, 1-hydroxy-	116-09-6	74.00												
2-Propanol, 2-methyl-	75-65-0	74.00												
1,2-Propanediol	57-55-6	76.00												
Propylene Glycol	57-55-6	76.00												
2-Ethylacrolein	922-63-4	84.00												
1-Pentene, 2-methyl-	763-29-1	84.00												
Oxetane, 3,3-dimethyl-	6921-35-3	86.00												
Pentane, 3-methyl-	96-14-0	86.00												
1,3-Oxathiolane	2094-97-5	90.00									7.41	0.58	2.01	0.16
Phenol	108-95-2	94.00												
Hexanal	66-25-1	100.00												
Butanoic acid, 2-methyl-	116-53-0	102.00												
1-Hexanol	111-27-3	102.00												
3-Methylpentan-1-ol	589-35-5	102.00												
Benzaldehyde	100-52-7	106.00	4.1	2.2	3.97	2.2								
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00												
Acetophenone	98-86-2	120.00												
Benzeneacetaldehyde	122-78-1	120.00												
Benzene, 1,2,3-trimethyl-	526-73-8	120.00												
Benzene, 1,2,4-trimethyl-	95-63-6	120.00					4.23	0.59	0.861	0.12				
Benzene, 1,3,5-trimethyl-	108-67-8	120.00												
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00									4.2	0.77	0.855	0.16
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00												
Benzoic acid	65-85-0	122.00	10.4	2.5	6.61	2.5								
Cycloalkane	64742-48-9	126.00												
Cyclohexane, propyl-	1678-92-8	126.00												
Azulene	275-51-4	128.00												
Naphthalene	91-20-3	128.00					4.64	0.62	0.885	0.12	4.77	0.82	0.911	0.16
Octane, 2-methyl	3221-61-2	128.00												
Octane, 3-methyl-	2216-33-3	128.00												
Octane, 4-methyl-	2216-34-4	128.00												
Formic acid, hexyl ester	629-33-4	130.00												
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00												
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00					4.54	0.65	0.829	0.12				
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00												
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00									5.11	0.86	0.932	0.16
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00												
2-Coumaranone	553-86-6	134.00												
1-Decene	872-05-9	140.00												
1-Undecanol	112-42-5	140.00												
2-Butenoic acid, butyl ester	7299-91-4	142.00												

Table 25. EPA TO-17 Target Compound Summary (May16, 2022 Eastman 2389, MW 142-266Mobil Jet Oil 387-1)

			Monday 5/16/2022, 17:15				Monday 5/16/2022, 14:50				Monday 5/16/2022, 14:50			
EPA Method TO-17 - Tenax			Sample # 463638		Sample # 463641		Sample # A035217				Sample # A035205			
Contaminant			n/a		n/a		Baseline				Baseline			
Bleed Temperature °C			n/a		n/a		200 °C				200 °C			
Sample Location			Field Blank		Ship Blank		Inlet				Bleed			
Analyte	CAS Number	MW	Result ng/tube	Report Limit ng/tube	Result ng/tube	Report Limit ng/tube	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00			3.14	2.9								
Decane	124-18-5	142.00					14.6	0.69	2.51	0.12	13.7	0.91	2.36	0.16
Nonanal	124-19-6	142.00	11	2.9										
Nonane, 4-methyl-	17301-94-9	142.00												
Octane, 2,6-dimethyl-	2051-30-1	142.00												
Hexanoic acid, 2-ethyl-	149-57-5	144.00					4.81	0.7	0.817	0.12	5.47	0.92	0.928	0.16
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00												
Phthalic anhydride	85-44-9	148.00												
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00												
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00												
n-Amylcyclohexane	29949-27-7	154.00												
Decanal	112-31-2	156.00	13.3	3.2										
Decane, 3-methyl-	13151-34-3	156.00												
Decane, 4-methyl-	2847-72-5	156.00					5.98	0.76	0.937	0.12				
Nonane, 2,6-dimethyl-	17302-28-2	156.00									5.99	1	0.938	0.16
Undecane	1120-21-4	156.00					21	0.76	3.29	0.12	24.5	1	3.84	0.16
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00												
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00					13.5	0.79	2.03	0.12	14.6	1	2.2	0.16
Decane, 3,6-dimethyl-	17312-53-7	170.00												
Dodecane	112-40-3	170.00					23.1	0.83	3.32	0.12	26.2	1.1	3.77	0.16
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00												
Undecane, 2-methyl-	7045-71-8	170.00												
Undecane, 3-methyl-	1002-43-3	170.00												
Undecane, 4-methyl-	2980-69-0	170.00									5.99	1.1	0.861	0.16
Undecane, 5-methyl-	1632-70-8	170.00					5.52	0.83	0.794	0.12				
Undecane, 6-methyl-	17302-33-9	170.00												
Phenylmaleic anhydride	36122-35-7	174.00	5.86	3.6										
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00												
Dodecane, 2-methyl-	1560-97-0	184.00												
Dodecane, 4-methyl-	6117-97-1	184.00												
Dodecane, 6-methyl-	6044-71-9	184.00					13.1	0.9	1.73	0.12	13.1	0.9	1.73	0.12
Tridecane	629-50-5	184.00					19.9	0.9	2.65	0.12	21.1	1.2	2.8	0.16
Undecane, 2,6-dimethyl-	17301-23-4	184.00												
Undecane, 2,10-dimethyl-	17301-27-8	184.00												
Undecane, 3,6-dimethyl-	17301-28-9	184.00												
Cyclotetradecane	295-17-0	196.00												
Tetradecane	629-59-4	198.00					10.6	0.96	1.31	0.12	11.1	1.3	1.38	0.16
Tridecane, 2-methyl-	1560-96-9	198.00					6.66	0.96	0.822	0.12	6.75	1.3	0.833	0.16
Tridecane, 3-methyl-	6418-41-3	198.00												
Tridecane, 6-methyl-	13287-21-3	198.00												
Tridecane, 7-methyl	26730-14-3	198.00												
Dodecane, 2,5-dimethyl-	56292-65-0	198.00												
Dodecanoic acid	143-07-7	200.00												
2,4-Di-tert-butylphenol	96-76-4	206.00												
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00												
Pentadecane	629-62-9	212.00					7.9	1	0.911	0.12	8.12	1.4	0.937	0.16
Tetradecane, 3-methyl-	18435-22-8	212.00												
Diethyl Phthalate	84-66-2	222.00	14.5	4.5										
Pentadecane, 7-methyl-	6165-40-8	226.00												
Tridecane, 5-propyl-	55045-11-9	226.00												
2,6,10-Trimethyltridecane	3891-99-4	226.00												
Octadecane	593-45-3	254.00												
Tributyl phosphate	126-73-8	266.00												
Triisobutyl phosphate	126-71-6	266.00												

Table 26. EPA TO-17 Target Compound Summary (May16, 2022 Eastman 2389, MW 41-142Mobil Jet Oil 387)

			Monday 5/16/2022, 16:50				Monday 5/16/2022, 16:50				Monday 5/16/2022, 18:50				Monday 5/16/2022, 18:50			
EPA Method TO-17 - Tenax			Sample # 463636				Sample # 463637				Sample # A035254				Sample # 463647			
Contaminant			Eastman 2389, 3 cSt Oil				Eastman 2389, 3 cSt Oil				Eastman 2389, 3 cSt Oil				Eastman 2389, 3 cSt Oil			
Bleed Temperature °C			200 °C				200 °C				260 °C				260 °C			
Sample Location			Inlet				Bleed				Inlet				Bleed			
Analyte	**CAS Number**	**MW**	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
Acetonitrile	75-05-8	41.00									2.05	0.19	1.22	0.11				
Methyl isocyanide	593-75-9	41.00																
Formic acid	64-18-6	46.00																
2-Propenal	107-02-8	56.00																
Acetone	67-64-1	58.00									2.15	0.27	0.907	0.11				
Isopropyl Alcohol	67-63-0	60.00																
1,4-Pentadiene	591-93-5	68.00																
Butanal	123-72-8	72.00																
3-Buten-2-one	78-94-4	70.00																
Cyclopentane	287-92-3	70.00																
Butane, 2-methyl-	78-78-4	72.00	8.28	0.34	2.73	0.11	6.66	0.38	2.2	0.13								
Pentane	109-66-0	72.00																
1-Butanol	71-36-3	74.00									10.1	0.34	3.32	0.11	6.31	0.36	2.08	0.12
2-Propanone, 1-hydroxy-	116-09-6	74.00																
2-Propanol, 2-methyl-	75-65-0	74.00																
1,2-Propanediol	57-55-6	76.00																
Propylene Glycol	57-55-6	76.00																
2-Ethylacrolein	922-63-4	84.00													10.6	0.41	3.07	0.12
1-Pentene, 2-methyl-	763-29-1	84.00																
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																
Pentane, 3-methyl-	96-14-0	86.00																
1,3-Oxathiolane	2094-97-5	90.00																
Phenol	108-95-2	94.00																
Hexanal	66-25-1	100.00													4.1	0.49	1	0.12
Butanoic acid, 2-methyl-	116-53-0	102.00																
1-Hexanol	111-27-3	102.00																
3-Methylpentan-1-ol	589-35-5	102.00																
Benzaldehyde	100-52-7	106.00																
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																
Acetophenone	98-86-2	120.00									3.85	0.56	0.784	0.11				
Benzeneacetaldehyde	122-78-1	120.00																
Benzene, 1,2,3-trimethyl-	526-73-8	120.00																
Benzene, 1,2,4-trimethyl-	95-63-6	120.00	3.93	0.56	0.8	0.11									3.62	0.59	0.738	0.12
Benzene, 1,3,5-trimethyl-	108-67-8	120.00									4.21	0.56	0.857	0.11				
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00					3.64	0.61	0.74	0.13								
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00	3.8	0.56	0.774	0.11												
Benzoic acid	65-85-0	122.00																
Cycloalkane	64742-48-9	126.00									4.5	0.59	0.873	0.11				
Cyclohexane, propyl-	1678-92-8	126.00	3.84	0.59	0.745	0.11					8.73	0.59	1.69	0.11	4.94	0.61	0.957	0.12
Azulene	275-51-4	128.00																
Naphthalene	91-20-3	128.00	4.58	0.6	0.874	0.11	4.26	0.66	0.81	0.13								
Octane, 2-methyl	3221-61-2	128.00													4.67	0.62	0.892	0.12
Octane, 3-methyl-	2216-33-3	128.00									7.72	0.6	1.47	0.11	4.15	0.62	0.793	0.12
Octane, 4-methyl-	2216-34-4	128.00									7.47	0.6	1.43	0.11				
Formic acid, hexyl ester	629-33-4	130.00																
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00	4.37	0.62	0.797	0.11												
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00									4.31	0.62	0.785	0.11				
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00					3.88	0.69	0.71	0.13								
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00																
2-Coumaranone	553-86-6	134.00																
1-Decene	872-05-9	140.00																
1-Undecanol	112-42-5	140.00																
2-Butenoic acid, butyl ester	7299-91-4	142.00																

Table 27. EPA TO-17 Target Compound Summary (May16, 2022 Eastman 2389, MW 142-2664)

			Monday 5/16/2022, 16:50				Monday 5/16/2022, 16:50				Monday5/16/2022, 18:50				Monday 5/16/2022, 18:50			
EPA Method TO-17 - Tenax			Sample #463636				Sample # 463637				Sample # A035254				Sample # 463647			
Contaminant			Eastman 2389, 3 cSt Oil				Eastman 2389, 3 cSt Oil				Eastman 2389, 3 cSt Oil				Eastman 2389, 3 cSt Oil			
Bleed Temperature °C			200 °C				200 °C				260 °C				260 °C			
Sample Location			Inlet				Bleed				Inlet				Bleed			
Analyte	**CAS Number**	**MW**	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																
Decane	124-18-5	142.00	12.9	0.66	2.22	0.11	13.1	0.73	2.26	0.13	17.5	0.66	3.02	0.11	12.8	0.69	2.21	0.12
Nonanal	124-19-6	142.00					4.41	0.73	0.76	0.13					4.39	0.69	0.756	0.12
Nonane, 4-methyl-	17301-94-9	142.00																
Octane, 2,6-dimethyl-	2051-30-1	142.00					5.54	0.73	0.95	0.13								
Hexanoic acid, 2-ethyl-	149-57-5	144.00	4.54	0.67	0.771	0.11	5.26	0.74	0.89	0.13								
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																
Phthalic anhydride	85-44-9	148.00	5.86	0.69	0.968	0.11												
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																
n-Amylcyclohexane	29949-27-7	154.00	4.86	0.72	0.771	0.11												
Decanal	112-31-2	156.00					4.46	0.8	0.7	0.13					6.34	0.76	0.994	0.12
Decane, 3-methyl-	13151-34-3	156.00																
Decane, 4-methyl-	2847-72-5	156.00	5.72	0.73	0.897	0.11	5.76	0.8	0.9	0.13	6.97	0.73	1.09	0.11	5.78	0.76	0.905	0.12
Nonane, 2,6-dimethyl-	17302-28-2	156.00																
Undecane	1120-21-4	156.00	18.6	0.73	2.92	0.11	24.6	0.8	3.85	0.13	17.8	0.73	2.79	0.11	13.8	0.76	2.15	0.12
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	12.7	0.75	1.92	0.11	12.1	0.83	1.83	0.13	8.79	0.75	1.33	0.11	9.93	0.79	1.5	0.12
Decane, 3,6-dimethyl-	17312-53-7	170.00																
Dodecane	112-40-3	170.00	18.4	0.62	3.35	0.11	24.1	0.87	3.46	0.13	19	0.79	2.74	0.11	18.7	0.83	2.7	0.12
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																
Undecane, 2-methyl-	7045-71-8	170.00					4.86	0.87	0.7	0.13								
Undecane, 3-methyl-	1002-43-3	170.00																
Undecane, 4-methyl-	2980-69-0	170.00																
Undecane, 5-methyl-	1632-70-8	170.00					5.93	0.87	0.85	0.13								
Undecane, 6-methyl-	17302-33-9	170.00									5	0.79	0.718	0.11				
Phenylmaleic anhydride	36122-35-7	174.00																
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																
Dodecane, 2-methyl-	1560-97-0	184.00					5.79	0.94	0.77	0.13								
Dodecane, 4-methyl-	6117-97-1	184.00																
Dodecane, 6-methyl-	6044-71-9	184.00					19.9	0.94	2.64	0.13	9.88	0.86	1.31	0.11				
Tridecane	629-50-5	184.00	20	0.86	2.66	0.11					16.8	0.86	2.24	0.11	17.1	0.9	2.27	0.12
Undecane, 2,6-dimethyl-	17301-23-4	184.00	13.1	0.86	1.74	0.11	12.9	0.94	1.71	0.13					10.1	0.9	1.35	0.12
Undecane, 2,10-dimethyl-	17301-27-8	184.00																
Undecane, 3,6-dimethyl-	17301-28-9	184.00																
Cyclotetradecane	295-17-0	196.00																
Tetradecane	629-59-4	198.00	11.5	0.92	1.41	0.11	11	1	1.36	0.13	10.5	0.92	1.29	0.11	10.2	0.96	1.26	0.12
Tridecane, 2-methyl-	1560-96-9	198.00																
Tridecane, 3-methyl-	6418-41-3	198.00																
Tridecane, 6-methyl-	13287-21-3	198.00																
Tridecane, 7-methyl	26730-14-3	198.00									6.14	0.92	0.758	0.11				
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																
Dodecanoic acid	143-07-7	200.00																
2,4-Di-tert-butylphenol	96-76-4	206.00																
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																
Pentadecane	629-62-9	212.00					6.13	1.1	0.71	0.13					8.62	1	0.993	0.12
Tetradecane, 3-methyl-	18435-22-8	212.00																
Diethyl Phthalate	84-66-2	222.00	6.65	1	0.732	0.11												
Pentadecane, 7-methyl-	6165-40-8	226.00																
Tridecane, 5-propyl-	55045-11-9	226.00																
2,6,10-Trimethyltridecane	3891-99-4	226.00																
Octadecane	593-45-3	254.00																
Tributyl phosphate	126-73-8	266.00																
Triisobutyl phosphate	126-71-6	266.00																

Table 28. EPA TO-17 Target Compound Summary (May17, 2022, Mobil Jet II, MW 41-142)

EPA Method TO-17 - Tenax			Tuesday 5/17/2022, 8:50				Tuesday 5/17/2022, 8:50				Tuesday 5/17/2022, 10:20				Tuesday 5/17/2022, 11:57				Tuesday 5/17/2022, 11:57			
			Sample # 463634				Sample # 463631				Sample #463643				Sample # 463624				Sample # 463623			
Fluid			Baseline				Baseline				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil			
Bleed Temperature °C			200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
Acetonitrile	75-05-8	41.00																				
Methyl isocyanide	593-75-9	41.00																				
Formic acid	64-18-6	46.00																				
2-Propenal	107-02-8	56.00																				
Acetone	67-64-1	58.00																				
Isopropyl Alcohol	67-63-0	60.00													1.71	0.27	0.698	0.11				
1,4-Pentadiene	591-93-5	68.00																				
Butanal	123-72-8	72.00																				
3-Buten-2-one	78-94-4	70.00																				
Cyclopentane	287-92-3	70.00																				
Butane, 2-methyl-	78-78-4	72.00																				
Pentane	109-66-0	72.00																				
1-Butanol	71-36-3	74.00	40.2	0.42	13.3	0.14	7.05	0.38	2.33	0.13	7.82	0.38	2.58	0.13	36.3	0.33	12	0.11	5.92	0.34	1.95	0.11
2-Propanone, 1-hydroxy-	116-09-6	74.00																				
2-Propanol, 2-methyl-	75-65-0	74.00																				
1,2-Propanediol	57-55-6	76.00																				
Propylene Glycol	57-55-6	76.00																				
2-Ethylacrolein	922-63-4	84.00																				
1-Pentene, 2-methyl-	763-29-1	84.00																				
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																				
Pentane, 3-methyl-	96-14-0	86.00																				
1,3-Oxathiolane	2094-97-5	90.00																				
Phenol	108-95-2	94.00																				
Hexanal	66-25-1	100.00																				
Butanoic acid, 2-methyl-	116-53-0	102.00																	3.17	0.47	0.76	0.11
1-Hexanol	111-27-3	102.00																				
3-Methylpentan-1-ol	589-35-5	102.00																				
Benzaldehyde	100-52-7	106.00																				
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																				
Acetophenone	98-86-2	120.00																				
Benzeneacetaldehyde	122-78-1	120.00																				
Benzene, 1,2,3-trimethyl-	526-73-8	120.00																				
Benzene, 1,2,4-trimethyl-	95-63-6	120.00					1.96	0.61	0.398	0.13												
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																				
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																				
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																				
Benzoic acid	65-85-0	122.00	3.6	0.69	0.721	0.14									6.05	0.54	1.21	0.11				
Cycloalkane	64742-48-9	126.00																				
Cyclohexane, propyl-	1678-92-8	126.00																				
Azulene	275-51-4	128.00																				
Naphthalene	91-20-3	128.00	4.3	0.73	0.821	0.14	2.24	0.66	0.427	0.13	4.35	0.66	0.83	0.13	3.42	0.57	0.652	0.11	5.15	0.6	0.98	0.11
Octane, 2-methyl	3221-61-2	128.00																				
Octane, 3-methyl-	2216-33-3	128.00																				
Octane, 4-methyl-	2216-34-4	128.00																				
Formic acid, hexyl ester	629-33-4	130.00																				
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00	3.48	0.76	0.634	0.14																
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																				
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																				
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																				
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00									4.23	0.69	0.772	0.13								
2-Coumaranone	553-86-6	134.00																				
1-Decene	872-05-9	140.00																				
1-Undecanol	112-42-5	140.00																				
2-Butenoic acid, butyl ester	7299-91-4	142.00																				

Table 29. EPA TO-17 Target Compound Summary (May17, 2022, Mobil Jet II, MW 142-266)

EPA Method TO-17 - Tenax			Tuesday 5/17/2022, 8:50				Tuesday 5/17/2022, 8:50				Tuesday 5/17/2022, 10:20				Tuesday 5/17/2022, 11:57				Tuesday 5/17/2022, 11:57			
			Sample # 463634				Sample # 463631				Sample #463643				Sample # 463624				Sample # 463623			
Fluid			Baseline				Baseline				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil			
Bleed Temperature °C			200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																				
Decane	124-18-5	142.00	9.48	0.81	1.63	0.14	6.78	0.73	1.17	0.13	5.71	0.73	0.983	0.13	6.17	0.63	1.06	0.11	9.87	0.66	1.7	0.11
Nonanal	124-19-6	142.00	4.65	0.81	0.8	0.14	3.6	0.73	0.619	0.13					4.75	0.63	0.818	0.11				
Nonane, 4-methyl-	17301-94-9	142.00																	4.62	0.66	0.8	0.11
Octane, 2,6-dimethyl-	2051-30-1	142.00																				
Hexanoicacid, 2-ethyl-	149-57-5	144.00	4.29	0.82	0.728	0.14									3.64	0.64	0.618	0.11				
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																				
Phthalic anhydride	85-44-9	148.00																				
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																				
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00	4.54	0.86	0.73	0.14																
n-Amylcyclohexane	29949-27-7	154.00	4.94	0.88	0.783	0.14									3.78	0.69	0.6	0.11				
Decanal	112-31-2	156.00	4.2	0.89	0.658	0.14	3.15	0.8	0.494	0.13	5.54	0.8	0.868	0.13	4.66	0.69	0.731	0.11	7.66	0.73	1.2	0.11
Decane, 3-methyl-	13151-34-3	156.00					3.37	0.8	0.528	0.13					3.88	0.69	0.608	0.11				
Decane, 4-methyl-	2847-72-5	156.00	4.31	0.89	0.675	0.14	2.88	0.8	0.451	0.13												
Nonane, 2,6-dimethyl-	17302-28-2	156.00																				
Undecane	1120-21-4	156.00	17.3	0.89	2.71	0.14	10.9	0.8	1.71	0.13	13.3	0.8	2.08	0.13	14.2	0.69	2.23	0.11	14.7	0.73	2.3	0.11
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																				
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	11.1	0.92	1.67	0.14	6.26	0.83	0.944	0.13	10.7	0.93	1.43	0.13	10.7	0.72	1.61	0.11	9.58	0.75	1.44	0.11
Decane, 3,6-dimethyl-	17312-53-7	170.00													4.16	0.76	0.599	0.11				
Dodecane	112-40-3	170.00	18.4	0.97	2.65	0.14	11.9	0.87	1.71	0.13	21.9	0.87	3.14	0.13	17.1	0.76	2.46	0.11	30.5	0.79	4.38	0.11
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																				
Undecane, 2-methyl-	7045-71-8	170.00	4.34	0.97	0.624	0.14					4.42	0.87	0.635	0.13								
Undecane, 3-methyl-	1002-43-3	170.00																				
Undecane, 4-methyl-	2980-69-0	170.00					3.05	0.87	0.438	0.13	4.45	0.87	0.64	0.13					6.69	0.79	0.96	0.11
Undecane, 5-methyl-	1632-70-8	170.00	5.6	0.97	0.805	0.14																
Undecane, 6-methyl-	17302-33-9	170.00																				
Phenylmaleic anhydride	36122-35-7	174.00																				
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																				
Dodecane, 2-methyl-	1560-97-0	184.00					3	0.94	0.398	0.13					4.51	0.82	0.599	0.11				
Dodecane, 4-methyl-	6117-97-1	184.00																				
Dodecane, 6-methyl-	6044-71-9	184.00													9.26	0.82	1.23	0.11				
Tridecane	629-50-5	184.00	13.2	1.1	1.76	0.14	9.72	0.94	1.29	0.13	18.3	0.94	2.43	0.13	15.5	0.82	2.06	0.11	26.6	0.86	3.53	0.11
Undecane, 2,6-dimethyl-	17301-23-4	184.00					6.63	0.94	0.881	0.13	12.8	0.94	1.69	0.13								
Undecane, 2,10-dimethyl-	17301-27-8	184.00									6.04	0.94	0.802	0.13								
Undecane, 3,6-dimethyl-	17301-28-9	184.00	10.2	1.1	1.35	0.14													17.1	0.86	2.27	0.11
Cyclotetradecane	295-17-0	196.00																				
Tetradecane	629-59-4	198.00	7.5	1.1	0.926	0.14	5.52	1	0.682	0.13	11.7	1	1.44	0.13	8.75	0.88	1.08	0.11	12.8	0.92	1.58	0.11
Tridecane, 2-methyl-	1560-96-9	198.00																	6.29	0.92	0.78	0.11
Tridecane, 3-methyl-	6418-41-3	198.00																				
Tridecane, 6-methyl-	13287-21-3	198.00																				
Tridecane, 7-methyl	26730-14-3	198.00					3.89	1	0.48	0.13	8.31	1	1.03	0.13								
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																				
Dodecanoic acid	143-07-7	200.00																				
2,4-Di-tert-butylphenol	96-76-4	206.00																				
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																				
Pentadecane	629-62-9	212.00					4.14	1.1	0.477	0.13	7.1	1.1	0.819	0.13	5.98	0.94	0.689	0.11	7.49	0.99	0.86	0.11
Tetradecane, 3-methyl-	18435-22-8	212.00																				
Diethyl Phthalate	84-66-2	222.00																				
Pentadecane, 7-methyl-	6165-40-8	226.00																				
Tridecane, 5-propyl-	55045-11-9	226.00																				
2,6,10-Trimethyltridecane	3891-99-4	226.00																				
Octadecane	593-45-3	254.00																				
Tributyl phosphate	126-73-8	266.00																				
Triisobutyl phosphate	126-71-6	266.00																				

Table 30. EPA TO-17 Target Compound Summary (May17, 2022, Mobil Jet 387, MW 41-142)

EPA Method TO-17 - Tenax			Tuesday 5/17/2022, 15:18				Tuesday 5/17/2022, 15:18				Tuesday 5/17/2022, 16:50				Tuesday5/17/2022, 16:50				Tuesday 5/17/2022, 18:20				Tuesday 5/17/2022, 18:20				Wednesday 5/17/2022, 17:20	
			Sample # 463648				Sample # 463639				Sample # 463626				Sample # 463633				Sample # 463625				Sample #463646				Sample # 463622	
Fluid			Baseline				Baseline				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 c St HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				n/a	
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C				n/a	
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed				Field Blank	
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube
Acetonitrile	75-05-8	41.00																									1.11	0.84
Methyl isocyanide	593-75-9	41.00																										
Formic acid	64-18-6	46.00																										
2-Propenal	107-02-8	56.00																										
Acetone	67-64-1	58.00																									2.03	1.2
Isopropyl Alcohol	67-63-0	60.00																										
1,4-Pentadiene	591-93-5	68.00																										
Butanal	123-72-8	72.00																										
3-Buten-2-one	78-94-4	70.00																										
Cyclopentane	287-92-3	70.00																										
Butane, 2-methyl-	78-78-4	72.00																										
Pentane	109-66-0	72.00																										
1-Butanol	71-36-3	74.00	3.51	0.32	1.16	0.1	4.83	0.34	1.59	0.11	4.94	0.38	1.63	0.13	4.74	0.38	1.56	0.13	5.1	0.36	1.68	0.12					1.9	1.5
2-Propanone, 1-hydroxy-	116-09-6	74.00																										
2-Propanol, 2-methyl-	75-65-0	74.00																										
1,2-Propanediol	57-55-6	76.00																										
Propylene Glycol	57-55-6	76.00																										
2-Ethylacrolein	922-63-4	84.00																										
1-Pentene, 2-methyl-	763-29-1	84.00																										
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																										
Pentane, 3-methyl-	96-14-0	86.00																										
1,3-Oxathiolane	2094-97-5	90.00																										
Phenol	108-95-2	94.00																										
Hexanal	66-25-1	100.00																										
Butanoic acid, 2-methyl-	116-53-0	102.00																										
1-Hexanol	111-27-3	102.00																										
3-Methylpentan-1-ol	589-35-5	102.00																										
Benzaldehyde	100-52-7	106.00																									3.19	2.2
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																										
Acetophenone	98-86-2	120.00																										
Benzeneacetaldehyde	122-78-1	120.00																										
Benzene, 1,2,3-trimethyl-	526-73-8	120.00	4.15	0.51	0.846	0.1																						
Benzene, 1,2,4-trimethyl-	95-63-6	120.00									5.17	0.61	1.05	0.13														
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																										
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00	4.39	0.51	0.894	0.1																						
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																										
Benzoic acid	65-85-0	122.00	9.77	0.52	1.96	0.1					8.54	0.62	1.71	0.13					10.4	0.59	2.09	0.12					7.19	2.5
Cycloalkane	64742-48-9	126.00									4.51	0.64	0.875	0.13														
Cyclohexane, propyl-	1678-92-8	126.00	4.39	0.54	0.852	0.1					5.47	0.66	1.04	0.13	4.84	0.66	0.924	0.13	4.74	0.62	0.91	0.12	4.07	0.66	0.778	0.13		
Azulene	275-51-4	128.00																										
Naphthalene	91-20-3	128.00	5.18	0.55	0.989	0.1	5.15	0.6	0.982	0.11																		
Octane, 2-methyl	3221-61-2	128.00																										
Octane, 3-methyl-	2216-33-3	128.00																										
Octane, 4-methyl-	2216-34-4	128.00																										
Formic acid, hexyl ester	629-33-4	130.00																										
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																										
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																										
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																										
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																										
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00	5.14	0.57	0.937	0.1					5.4	0.69	0.985	0.13					5.4	0.65	0.99	0.12						
2-Coumaranone	553-86-6	134.00																										
1-Decene	872-05-9	140.00																										
1-Undecanol	112-42-5	140.00																										
2-Butenoic acid, butyl ester	7299-91-4	142.00																										

Table 31. EPA TO-17 Target Compound Summary (May17, 2022, Mobil Jet 387, MW 142-266)

EPA Method TO-17 - Tenax			Tuesday 5/17/2022, 15:18				Tuesday 5/17/2022, 15:18				Tuesday 5/17/2022, 16:50				Tuesday 5/17/2022, 16:50				Tuesday 5/17/2022, 18:20				Tuesday 5/17/2022, 18:20				Wednesday 5/17/2022, 17:20	
			Sample # 463648				Sample # 463639				Sample # 463626				Sample # 463633				Sample # 463625				Sample # 463646				Sample # 463622	
Fluid			Baseline				Baseline				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				n/a	
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C				n/a	
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed				Field Blank	
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																										
Decane	124-18-5	142.00	15.4	0.61	2.65	0.1	14.3	0.66	2.45	0.11	18.3	0.73	3.15	0.13	10.6	0.73	1.83	0.13	7.88	0.69	1.36	0.12	8.08	0.73	1.39	0.13		
Nonanal	124-19-6	142.00																									3.77	2.9
Nonane, 4-methyl-	17301-94-9	142.00									5.22	0.73	0.898	0.13														
Octane, 2,6-dimethyl-	2051-30-1	142.00																										
Hexanoic acid, 2-ethyl-	149-57-5	144.00																										
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																										
Phthalic anhydride	85-44-9	148.00																										
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																										
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																										
n-Amylcyclohexane	29949-27-7	154.00																										
Decanal	112-31-2	156.00					8.75	0.73	1.37	0.11					6.88	0.8	1.08	0.13					7.56	0.8	1.18	0.13		
Decane, 3-methyl-	13151-34-3	156.00	6.35	0.67	0.995	0.1	5.57	0.73	0.872	0.11																		
Decane, 4-methyl-	2847-72-5	156.00									8.37	0.8	1.31	0.13														
Nonane, 2,6-dimethyl-	17302-28-2	156.00																										
Undecane	1120-21-4	156.00	16.9	0.67	2.64	0.1	15	0.73	2.34	0.11	20.2	0.8	3.17	0.13	13.2	0.8	2.06	0.13	13.5	0.76	2.11	0.12	10.3	0.8	1.62	0.13		
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																										
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	12.8	0.69	1.93	0.1	9.49	0.75	1.43	0.11	14.1	0.83	2.12	0.13	9.74	0.83	1.47	0.13	14.8	0.79	2.23	0.12	9	0.83	1.36	0.13		
Decane, 3,6-dimethyl-	17312-53-7	170.00																										
Dodecane	112-40-3	170.00	27	0.73	3.89	0.1	32.8	0.79	4.71	0.11	27.6	0.87	3.96	0.13	27.8	0.87	4	0.13	26.2	0.83	3.77	0.12	25.5	0.87	3.67	0.13		
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																										
Undecane, 2-methyl-	7045-71-8	170.00																	5.06	0.83	0.73	0.12						
Undecane, 3-methyl-	1002-43-3	170.00									7.47	0.87	1.07	0.13														
Undecane, 4-methyl-	2980-69-0	170.00					6.57	0.79	0.944	0.11																		
Undecane, 5-methyl-	1632-70-8	170.00																										
Undecane, 6-methyl-	17302-33-9	170.00																										
Phenylmaleic anhydride	36122-35-7	174.00																										
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																									6.53	3.7
Dodecane, 2-methyl-	1560-97-0	184.00					8.85	0.86	1.18	0.11					8.14	0.94	1.08	0.13										
Dodecane, 4-methyl-	6117-97-1	184.00																										
Dodecane, 6-methyl-	6044-71-9	184.00	15.5	0.78	2.05	0.1	17.9	0.86	2.38	0.11	15.6	0.94	2.07	0.13					13.5	0.9	1.79	0.12	13.5	0.94	1.79	0.13		
Tridecane	629-50-5	184.00	34.5	0.78	4.58	0.1	32.2	0.86	4.28	0.11	28.5	0.94	3.79	0.13	29.4	0.94	3.91	0.13	26.6	0.9	3.53	0.12	28	0.94	3.72	0.13		
Undecane, 2,6-dimethyl-	17301-23-4	184.00													15.6	0.94	2.07	0.13										
Undecane, 2,10-dimethyl-	17301-27-8	184.00	7.83	0.78	1.04	0.1																						
Undecane, 3,6-dimethyl-	17301-28-9	184.00																										
Cyclotetradecane	295-17-0	196.00																										
Tetradecane	629-59-4	198.00	16.8	0.84	2.08	0.1	17.6	0.99	2.03	0.11	16.8	1	2.08	0.13	18.7	1	2.31	0.13	15.1	0.96	1.87	0.12	14.8	1	1.82	0.13		
Tridecane, 2-methyl-	1560-96-9	198.00	9.18	0.84	1.13	0.1	7.99	0.92	0.987	0.11	7.34	1	0.906	0.13	7.62	1	0.941	0.13	6.71	0.96	0.83	0.12						
Tridecane, 3-methyl-	6418-41-3	198.00																	6.07	0.96	0.75	0.12						
Tridecane, 6-methyl-	13287-21-3	198.00									8.43	1	1.04	0.13	9.31	1	1.15	0.13										
Tridecane, 7-methyl	26730-14-3	198.00									12	1	1.48	0.13									11.9	1	1.47	0.13		
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																										
Dodecanoic acid	143-07-7	200.00																										
2,4-Di-tert-butylphenol	96-76-4	206.00																										
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																	6.8	1	0.78	0.12						
Pentadecane	629-62-9	212.00	11.6	0.9	1.34	0.1	9.97	0.99	1.15	0.11	11.9	1.1	1.38	0.13	14.1	1.1	1.63	0.13	11.3	1	1.3	0.12	8.08	1.1	0.931	0.13		
Tetradecane, 3-methyl-	18435-22-8	212.00																										
Diethyl Phthalate	84-66-2	222.00																										
Pentadecane, 7-methyl-	6165-40-8	226.00																	7.18	1.1	0.78	0.12						
Tridecane, 5-propyl-	55045-11-9	226.00													9.14	1.2	0.989	0.13										
2,6,10-Trimethyltridecane	3891-99-4	226.00																										
Octadecane	593-45-3	254.00																										
Tributyl phosphate	126-73-8	266.00																										
Triisobutyl phosphate	126-71-6	266.00																										

Table 32. EPA TO-17 Target Compound Summary (May18, 2022, Skydrol PE-5, MW 41-142)

EPA Method TO-17 - Tenax			Wednesday 5/18/2022, 8:30				Wednesday 5/18/2022, 8:30				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55			
			Sample # 463642				Sample #463635				Sample # A035183				Sample #463644				Sample # 463650				Sample #A034773			
Fluid			Baseline				Baseline				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid			
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
Acetonitrile	75-05-8	41.00					1.1	0.28	0.66	0.17					2.71	0.21	1.62	0.13					1.02	0.26	0.607	0.16
Methyl isocyanide	593-75-9	41.00																								
Formic acid	64-18-6	46.00																								
2-Propenal	107-02-8	56.00																								
Acetone	67-64-1	58.00																					2.59	0.37	1.09	0.16
Isopropyl Alcohol	67-63-0	60.00																								
1,4-Pentadiene	591-93-5	68.00																								
Butanal	123-72-8	72.00																					2.1	0.46	0.714	0.16
3-Buten-2-one	78-94-4	70.00																					3.07	0.45	1.07	0.16
Cyclopentane	287-92-3	70.00													4.87	0.36	1.7	0.13								
Butane, 2-methyl-	78-78-4	72.00																								
Pentane	109-66-0	72.00																								
1-Butanol	71-36-3	74.00	4.94	0.58	1.63	0.19	5.06	0.51	1.67	0.17	5.88	0.34	1.94	0.11	14.4	0.38	4.75	0.13	6.03	0.36	1.99	0.12	19	0.47	6.28	0.16
2-Propanone, 1-hydroxy-	116-09-6	74.00																								
2-Propanol, 2-methyl-	75-65-0	74.00													2.07	0.38	0.682	0.13								
1,2-Propanediol	57-55-6	76.00																								
Propylene Glycol	57-55-6	76.00																								
2-Ethylacrolein	922-63-4	84.00																								
1-Pentene, 2-methyl-	763-29-1	84.00																								
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																								
Pentane, 3-methyl-	96-14-0	86.00													13.1	0.44	3.72	0.13								
1,3-Oxathiolane	2094-97-5	90.00																								
Phenol	108-95-2	94.00																								
Hexanal	66-25-1	100.00																								
Butanoic acid, 2-methyl-	116-53-0	102.00																								
1-Hexanol	111-27-3	102.00																								
3-Methylpentan-1-ol	589-35-5	102.00																								
Benzaldehyde	100-52-7	106.00																								
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00	2.04	0.88	0.446	0.19																				
Acetophenone	98-86-2	120.00	2.17	0.94	0.441	0.19	3.48	0.82	0.71	0.17																
Benzeneacetaldehyde	122-78-1	120.00																								
Benzene, 1,2,3-trimethyl-	526-73-8	120.00	1.87	0.94	0.381	0.19																				
Benzene, 1,2,4-trimethyl-	95-63-6	120.00																								
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																								
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																								
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																								
Benzoic acid	65-85-0	122.00	7.75	0.96	1.55	0.19	13.3	0.83	2.67	0.17	6.29	0.57	1.26	0.11					6.84	0.59	1.37	0.12				
Cycloalkane	64742-48-9	126.00																								
Cyclohexane, propyl-	1678-92-8	126.00	2	0.99	0.387	0.19																				
Azulene	275-51-4	128.00													3.42	0.66	0.652	0.13								
Naphthalene	91-20-3	128.00	2.14	1	0.409	0.19					2.19	0.6	0.418	0.11					1.98	0.62	0.378	0.12				
Octane, 2-methyl	3221-61-2	128.00																								
Octane, 3-methyl-	2216-33-3	128.00																								
Octane, 4-methyl-	2216-34-4	128.00																								
Formic acid, hexyl ester	629-33-4	130.00																								
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																								
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																								
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																								
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																								
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00																								
2-Coumaranone	553-86-6	134.00																								
1-Decene	872-05-9	140.00																								
1-Undecanol	112-42-5	140.00																								
2-Butenoic acid, butyl ester	7299-91-4	142.00																								

Table 33. EPA TO-17 Target Compound Summary (May18, 2022, Skydrol PE-5, MW 142-266)

EPA Method TO-17 - Tenax			Wednesday 5/18/2022, 8:30				Wednesday 5/18/2022, 8:30				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55			
			Sample # 463642				Sample # 463635				Sample # A035183				Sample #463644				Sample # 463650				Sample # A034773			
Fluid			Baseline				Baseline				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid			
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed			
Analyte	**CAS Number**	**MW**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																								
Decane	124-18-5	142.00	8.11	1.1	1.4	0.19	6.54	0.97	1.13	0.17	4.14	0.66	0.712	0.11					3.46	0.69	0.596	0.12	3.6	0.91	0.62	0.16
Nonanal	124-19-6	142.00	2.36	1.1	0.406	0.19	3.69	0.97	0.64	0.17					6.32	0.73	1.09	0.13	2.25	0.69	0.388	0.12				
Nonane, 4-methyl-	17301-94-9	142.00																								
Octane, 2,6-dimethyl-	2051-30-1	142.00																								
Hexanoic acid, 2-ethyl-	149-57-5	144.00	2.1	1.1	0.356	0.19																				
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																								
Phthalic anhydride	85-44-9	148.00																					4.02	0.95	0.663	0.16
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00									2.31	0.7	0.374	0.11												
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																								
n-Amylcyclohexane	29949-27-7	154.00																								
Decanal	112-31-2	156.00	2.68	1.2	0.419	0.19	3.38	1.1	0.53	0.17	3.76	0.73	0.589	0.11	6.84	0.8	1.07	0.13	2.11	0.76	0.33	0.12	3.03	1	0.475	0.16
Decane, 3-methyl-	13151-34-3	156.00					3.02	1.1	0.47	0.17																
Decane, 4-methyl-	2847-72-5	156.00	3.01	1.2	0.471	0.19	2.63	1.1	0.41	0.17																
Nonane, 2,6-dimethyl-	17302-28-2	156.00																								
Undecane	1120-21-4	156.00	8.48	1.2	1.33	0.19	7.95	1.1	1.25	0.17	7.09	0.73	1.11	0.11					6.63	0.76	1.04	0.12	6.32	1	0.991	0.16
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																	2.2	0.78	0.336	0.12				
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	6.65	1.3	1	0.19	5.82	1.1	0.88	0.17	6.74	0.75	1.02	0.11	7.25	0.83	1.09	0.13	6.42	0.79	0.969	0.12	5.15	1	0.777	0.16
Decane, 3,6-dimethyl-	17312-53-7	170.00																								
Dodecane	112-40-3	170.00	10.2	1.3	1.46	0.19	11	1.2	1.58	0.17	10.1	0.79	1.45	0.11	10.4	0.87	1.49	0.13	10.2	0.83	1.47	0.12	11.2	1.1	1.6	0.16
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00													21.8	0.87	3.13	0.13								
Undecane, 2-methyl-	7045-71-8	170.00	2.96	1.3	0.426	0.19																				
Undecane, 3-methyl-	1002-43-3	170.00																								
Undecane, 4-methyl-	2980-69-0	170.00																								
Undecane, 5-methyl-	1632-70-8	170.00																								
Undecane, 6-methyl-	17302-33-9	170.00																								
Phenylmaleic anhydride	36122-35-7	174.00					3.41	1.2	0.48	0.17	2.66	0.81	0.374	0.11												
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																								
Dodecane, 2-methyl-	1560-97-0	184.00																								
Dodecane, 4-methyl-	6117-97-1	184.00																								
Dodecane, 6-methyl-	6044-71-9	184.00									5.75	0.86	0.764	0.11	9.22	0.94	1.22	0.13								
Tridecane	629-50-5	184.00	10.6	1.5	1.41	0.19	11.3	1.3	1.51	0.17	11	0.86	1.47	0.11	13.9	0.94	1.85	0.13	11.1	0.9	1.48	0.12	13.2	1.2	1.76	0.16
Undecane, 2,6-dimethyl-	17301-23-4	184.00	5.82	1.5	0.773	0.19	6.05	1.3	0.8	0.17									5.4	0.9	0.718	0.12	5.05	1.2	0.671	0.16
Undecane, 2,10-dimethyl-	17301-27-8	184.00																								
Undecane, 3,6-dimethyl-	17301-28-9	184.00																								
Cyclotetradecane	295-17-0	196.00																								
Tetradecane	629-59-4	198.00	5.58	1.6	0.689	0.19	7.38	1.4	0.91	0.17	6.49	0.92	0.801	0.11	8.01	1	0.989	0.13	6.49	0.96	0.801	0.12	7.68	1.3	0.948	0.16
Tridecane, 2-methyl-	1560-96-9	198.00													5.22	1	0.644	0.13	2.72	0.96	0.336	0.12				
Tridecane, 3-methyl-	6418-41-3	198.00																	2.68	0.96	0.331	0.12				
Tridecane, 6-methyl-	13287-21-3	198.00																								
Tridecane, 7-methyl	26730-14-3	198.00					4.68	1.4	0.58	0.17	4.34	0.92	0.536	0.11					4.18	0.96	0.516	0.12	6.07	1.3	0.749	0.16
Dodecane, 2,5-dimethyl-	56292-65-0	198.00									3.87	0.92	0.478	0.11												
Dodecanoic acid	143-07-7	200.00																					5.27	1.3	0.644	0.16
2,4-Di-tert-butylphenol	96-76-4	206.00																								
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																								
Pentadecane	629-62-9	212.00									4.35	0.99	0.501	0.11	7.08	1.1	0.816	0.13	4.47	1	0.515	0.12	4.69	1.4	0.541	0.16
Tetradecane, 3-methyl-	18435-22-8	212.00																								
Diethyl Phthalate	84-66-2	222.00																					6.36	1.4	0.7	0.16
Pentadecane, 7-methyl-	6165-40-8	226.00																								
Tridecane, 5-propyl-	55045-11-9	226.00																								
2,6,10-Trimethyltridecane	3891-99-4	226.00																								
Octadecane	593-45-3	254.00																								
Tributyl phosphate	126-73-8	266.00																					23.6	1.7	2.17	0.16
Triisobutyl phosphate	126-71-6	266.00																								

Table 34. EPA TO-17 Target Compound Summary (May18, 2022, Hy-Jet IV-A+, MW 41-142)

EPA Method TO-17 - Tenax			Wednesday 5/18/2022, 14:32				Wednesday5/18/2022, 14:32				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 17:00		Wednesday 5/18/2022,	
			Sample # A035167				Sample # A035270				Sample # Y59084				Sample #Y59070				Sample # 673918				Sample # A673917				Sample # 673930		Sample # 673925	
Fluid			Baseline				Baseline				HyJet IV-A+Type IV Hydraulic Fluid				HyJet IV-A+Type IV Hydraulic Fluid				HyJet IV-A+Type IV Hydraulic Fluid				HyJet IV-A+ Type IV Hydraulic Fluid				n/a		n/a	
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C				n/a		n/a	
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed				Field Blank		Ship Blank	
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube	Result ng/tube	Report Limit ng/tube
Acetonitrile	75-05-8	41.00									1.13	0.2	0.676	0.12																
Methyl isocyanide	593-75-9	41.00																									1.31	0.84		
Formic acid	64-18-6	46.00													14.8	0.24	7.85	0.13												
2-Propenal	107-02-8	56.00																												
Acetone	67-64-1	58.00																												
Isopropyl Alcohol	67-63-0	60.00																												
1,4-Pentadiene	591-93-5	68.00																												
Butanal	123-72-8	72.00																												
3-Buten-2-one	78-94-4	70.00																					1.9	0.38	0.664	0.13				
Cyclopentane	287-92-3	70.00																												
Butane, 2-methyl-	78-78-4	72.00																												
Pentane	109-66-0	72.00																									1.62	1.5		
1-Butanol	71-36-3	74.00	5.3	0.4	1.75	0.13	5.21	0.42	1.72	0.14	5.76	0.36	1.9	0.12	9.76	0.38	3.22	0.13	4.11	0.36	1.36	0.12	14.3	0.4	4.71	0.13				
2-Propanone, 1-hydroxy-	116-09-6	74.00																											4.94	1.5
2-Propanol, 2-methyl-	75-65-0	74.00																												
1,2-Propanediol	57-55-6	76.00																												
Propylene Glycol	57-55-6	76.00																												
2-Ethylacrolein	922-63-4	84.00																												
1-Pentene, 2-methyl-	763-29-1	84.00																											2.34	1.7
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																												
Pentane, 3-methyl-	96-14-0	86.00																												
1,3-Oxathiolane	2094-97-5	90.00																												
Phenol	108-95-2	94.00																												
Hexanal	66-25-1	100.00																					2.81	0.54	0.687	0.13				
Butanoic acid, 2-methyl-	116-53-0	102.00																												
1-Hexanol	111-27-3	102.00													5.33	0.52	1.28	0.13												
3-Methylpentan-1-ol	589-35-5	102.00																					14	0.55	3.35	0.13				
Benzaldehyde	100-52-7	106.00																									3.75	2.2	3.43	2.2
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																												
Acetophenone	98-86-2	120.00									2.72	0.59	0.555	0.12	21.4	0.61	4.36	0.13									3.81	2.5	3.84	2.5
Benzeneacetaldehyde	122-78-1	120.00									2.15	0.59	0.438	0.12	7.91	0.61	1.61	0.13												
Benzene, 1,2,3-trimethyl-	526-73-8	120.00																												
Benzene, 1,2,4-trimethyl-	95-63-6	120.00																												
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																												
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																												
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																												
Benzoic acid	65-85-0	122.00	10.6	0.66	2.12	0.13	3.86	0.69	0.773	0.14	7.44	0.59	1.49	0.12	220	0.62	44.1	0.13	7.6	0.59	1.52	0.12	7.07	0.66	1.42	0.13	10.6	2.5	10.2	2.5
Cycloalkane	64742-48-9	126.00																												
Cyclohexane, propyl-	1678-92-8	126.00																												
Azulene	275-51-4	128.00																												
Naphthalene	91-20-3	128.00																												
Octane, 2-methyl	3221-61-2	128.00																												
Octane, 3-methyl-	2216-33-3	128.00																												
Octane, 4-methyl-	2216-34-4	128.00																												
Formic acid, hexyl ester	629-33-4	130.00																												
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																												
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																												
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																												
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																												
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00																												
2-Coumaranone	553-86-6	134.00													5.01	0.69	0.913	0.13												
1-Decene	872-05-9	140.00																									2.9	2.9		
1-Undecanol	112-42-5	140.00																												
2-Butenoic acid, butyl ester	7299-91-4	142.00					3.49	0.81	0.6	0.14																				

Table 35. EPA TO-17 Target Compound Summary (May18, 2022, Hy-Jet IV-A+, MW 142-266)

EPA Method TO-17 - Tenax			Wednesday 5/18/2022, 14:32				Wednesday5/18/2022, 14:32				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 17:00		Wednesday 5/18/2022,	
			Sample # A035167				Sample # A035270				Sample # Y59084				Sample #Y59070				Sample # 673918				Sample # A673917				Sample # 673930		Sample # 673925	
Fluid			Baseline				Baseline				HyJet IV-A+Type IV Hydraulic Fluid				lyJet IV-A+Type IV Hydraulic Fluid				yJet IV-A+Type IV Hydraulic Flui				HyJet IV-A+ Type IV Hydraulic Fluid				n/a		n/a	
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C				n/a		n/a	
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed				Field Blank		Ship Blank	
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube	Result ng/tube	Report Limit ng/tube
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																												
Decane	124-18-5	142.00					3.29	0.81	0.566	0.14	8.98	0.69	1.55	0.12	8.23	0.73	1.42	0.13	5.39	0.69	0.928	0.12	5.14	0.76	0.885	0.13				
Nonanal	124-19-6	142.00																	8.67	0.69	1.49	0.12	5.65	0.76	0.973	0.13				
Nonane, 4-methyl-	17301-94-9	142.00																												
Octane, 2,6-dimethyl-	2051-30-1	142.00																												
Hexanoic acid, 2-ethyl-	149-57-5	144.00																												
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00													4.06	0.76	0.67	0.13												
Phthalic anhydride	85-44-9	148.00																												
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																												
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																												
n-Amylcyclohexane	29949-27-7	154.00																												
Decanal	112-31-2	156.00					4.66	0.89	0.731	0.14									10.9	0.76	1.7	0.12	5.22	0.84	0.818	0.13				
Decane, 3-methyl-	13151-34-3	156.00																												
Decane, 4-methyl-	2847-72-5	156.00									2.76	0.76	0.433	0.12																
Nonane, 2,6-dimethyl-	17302-28-2	156.00																												
Undecane	1120-21-4	156.00	7.25	0.84	1.14	0.13	6.63	0.89	1.04	0.14	8.96	0.76	1.4	0.12	8.68	0.8	1.36	0.13	6.89	0.76	1.08	0.12	6.78	0.84	1.06	0.13				
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																												
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	8.01	0.87	1.21	0.13	7.11	0.92	1.07	0.14	6.92	0.79	1.04	0.12	7.31	0.83	1.1	0.13	7.49	0.79	1.13	0.12	7.05	0.87	1.06	0.13				
Decane, 3,6-dimethyl-	17312-53-7	170.00																												
Dodecane	112-40-3	170.00	13	0.92	1.87	0.13	12.4	0.97	1.78	0.14	12.5	0.83	1.79	0.12	12.9	0.87	1.86	0.13	11.4	0.83	1.63	0.12	10.2	0.92	1.46	0.13				
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																												
Undecane, 2-methyl-	7045-71-8	170.00																												
Undecane, 3-methyl-	1002-43-3	170.00																												
Undecane, 4-methyl-	2980-69-0	170.00																												
Undecane, 5-methyl-	1632-70-8	170.00																												
Undecane, 6-methyl-	17302-33-9	170.00																												
Phenylmaleic anhydride	36122-35-7	174.00																												
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																												
Dodecane, 2-methyl-	1560-97-0	184.00																												
Dodecane, 4-methyl-	6117-97-1	184.00									3.57	0.9	0.474	0.12																
Dodecane, 6-methyl-	6044-71-9	184.00	5.65	0.99	0.75	0.13	6.52	1.1	0.866	0.14	6.21	0.9	0.825	0.12	6.61	0.94	0.878	0.13	5.3	0.9	0.704	0.12	4.98	0.99	0.661	0.13				
Tridecane	629-50-5	184.00	18.5	0.99	2.46	0.13	18.1	1.1	2.4	0.14	16	0.9	2.12	0.12	18.9	0.94	2.51	0.13	15.2	0.9	2.02	0.12	16.6	0.99	2.21	0.13				
Undecane, 2,6-dimethyl-	17301-23-4	184.00																												
Undecane, 2,10-dimethyl-	17301-27-8	184.00																												
Undecane, 3,6-dimethyl-	17301-28-9	184.00																												
Cyclotetradecane	295-17-0	196.00																												
Tetradecane	629-59-4	198.00	17.6	1.1	2.17	0.13	10.7	1.1	1.32	0.14	10.6	0.96	1.3	0.12	11.7	1	1.45	0.13	11.2	0.96	1.38	0.12	11.3	1.1	1.39	0.13				
Tridecane, 2-methyl-	1560-96-9	198.00	8.34	1.1	1.03	0.13					4.13	0.96	0.51	0.12	5.16	1	0.637	0.13	4.55	0.96	0.562	0.12								
Tridecane, 3-methyl-	6418-41-3	198.00									3.76	0.96	0.464	0.12																
Tridecane, 6-methyl-	13287-21-3	198.00									4.29	0.96	0.529	0.12																
Tridecane, 7-methyl	26730-14-3	198.00					6.09	1.1	0.752	0.14	5.38	0.96	0.664	0.12	6.85	1	0.845	0.13	5.09	0.96	0.629	0.12	5.23	1.1	0.645	0.13				
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																												
Dodecanoic acid	143-07-7	200.00																	7.07	0.97	0.863	0.12	7.56	1.1	0.924	0.13	14.3	4.1	17.3	4.1
2,4-Di-tert-butylphenol	96-76-4	206.00																												
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00	6.81	1.1	0.785	0.13																								
Pentadecane	629-62-9	212.00	8.22	1.1	0.947	0.13	6.15	1.2	0.708	0.14	7.15	1	0.824	0.12	9.14	1.1	1.05	0.13	7.88	1	0.908	0.12	7.35	1.1	0.847	0.13				
Tetradecane, 3-methyl-	18435-22-8	212.00																												
Diethyl Phthalate	84-66-2	222.00	16.8	1.2	1.85	0.13																								
Pentadecane, 7-methyl-	6165-40-8	226.00																												
Tridecane, 5-propyl-	55045-11-9	226.00																												
2,6,10-Trimethyltridecane	3891-99-4	226.00																												
Octadecane	593-45-3	254.00	19.2	1.4	1.85	0.13																								
Tributyl phosphate	126-73-8	266.00					165	1.5	15.2	0.14					490	1.4	45	0.13					205	1.4	18.8	0.13				
Triisobutyl phosphate	126-71-6	266.00					95	1.5	8.73	0.14					22	1.4	2.02	0.13					18.1	1.4	1.67	0.13				

Table 36. EPA TO-17 Target Compound Summary (May19, 2022, Type 1 Deicing Fluid, MW 41-142)

EPA Method TO-17 - Tenax			Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 11:22	
			Sample # 673912				Sample # 673914				Sample # 673929				Sample # 673923				Sample # 673927	
Fluid			Baseline				Baseline				Type 1 Deicing Fluid				Type 1 Deicing Fluid				n/a	
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				n/a	
			Inlet				Bleed				Inlet				Bleed				Field Blank	
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube
Acetonitrile	75-05-8	41.00																	3.61	0.84
Methyl isocyanide	593-75-9	41.00																		
Formic acid	64-18-6	46.00																		
2-Propenal	107-02-8	56.00																	1.77	1.1
Acetone	67-64-1	58.00	0.893	0.27	0.376	0.11													4.19	1.2
Isopropyl Alcohol	67-63-0	60.00																		
1,4-Pentadiene	591-93-5	68.00																	1.94	1.4
Butanal	123-72-8	72.00																		
3-Buten-2-one	78-94-4	70.00																		
Cyclopentane	287-92-3	70.00																		
Butane, 2-methyl-	78-78-4	72.00																		
Pentane	109-66-0	72.00																	3.74	1.5
1-Butanol	71-36-3	74.00	2.9	0.34	0.959	0.11	5.58	0.51	1.84	0.17	4.44	0.3	1.47	0.1	5.72	0.33	1.89	0.11		
2-Propanone, 1-hydroxy-	116-09-6	74.00													3.11	0.33	1.03	0.11		
2-Propanol, 2-methyl-	75-65-0	74.00																		
1,2-Propanediol	57-55-6	76.00													270	0.34	86.9	0.11	2.02	1.6
Propylene Glycol	57-55-6	76.00																		
2-Ethylacrolein	922-63-4	84.00																		
1-Pentene, 2-methyl-	763-29-1	84.00																	3.57	1.7
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																	3.37	1.8
Pentane, 3-methyl-	96-14-0	86.00																	3.59	1.8
1,3-Oxathiolane	2094-97-5	90.00																		
Phenol	108-95-2	94.00																	2.28	1.9
Hexanal	66-25-1	100.00																		
Butanoic acid, 2-methyl-	116-53-0	102.00																		
1-Hexanol	111-27-3	102.00																		
3-Methylpentan-1-ol	589-35-5	102.00																		
Benzaldehyde	100-52-7	106.00																	4.22	2.2
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																		
Acetophenone	98-86-2	120.00	1.9	0.56	0.388	0.11	3.06	0.82	0.624	0.17	1.8	0.49	0.366	0.1					4.35	2.5
Benzeneacetaldehyde	122-78-1	120.00																		
Benzene, 1,2,3-trimethyl-	526-73-8	120.00																		
Benzene, 1,2,4-trimethyl-	95-63-6	120.00																		
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																		
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																		
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																		
Benzoic acid	65-85-0	122.00	5.81	0.57	1.16	0.11	5.31	0.83	1.06	0.17	5.54	0.5	1.11	0.1	4.11	0.54	0.823	0.11	13.6	2.5
Cycloalkane	64742-48-9	126.00																		
Cyclohexane, propyl-	1678-92-8	126.00																		
Azulene	275-51-4	128.00																		
Naphthalene	91-20-3	128.00																		
Octane, 2-methyl	3221-61-2	128.00																		
Octane, 3-methyl-	2216-33-3	128.00																		
Octane, 4-methyl-	2216-34-4	128.00																		
Formic acid, hexyl ester	629-33-4	130.00																		
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																		
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																		
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																		
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																		
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00																		
2-Coumaranone	553-86-6	134.00																		
1-Decene	872-05-9	140.00																		
1-Undecanol	112-42-5	140.00																		
2-Butenoic acid, butyl ester	7299-91-4	142.00																		

Table 37. EPA TO-17 Target Compound Summary (May19, 2022, Type 1 Deicing Fluid, MW 142-266)

EPA Method TO-17 - Tenax			Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 11:22	
			Sample # 673912				Sample # 673914				Sample # 673929				Sample # 673923				Sample # 673927	
Fluid			Baseline				Baseline				Type 1 Deicing Fluid				Type 1 Deicing Fluid				n/a	
ature °C			200 °C				200 °C				200 °C				200 °C				n/a	
			Inlet				Bleed				Inlet				Bleed				Field Blank	
	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																		
Decane	124-18-5	142.00	6.03	0.66	1.04	0.11	7.68	0.97	1.32	0.17	3.74	0.58	0.643	0.1	3.94	0.63	0.677	0.11		
Nonanal	124-19-6	142.00	7.44	0.66	1.28	0.11	3.73	0.97	0.642	0.17	4.36	0.58	0.751	0.1	3.5	0.63	0.602	0.11		
Nonane, 4-methyl-	17301-94-9	142.00																		
Octane, 2,6-dimethyl-	2051-30-1	142.00																		
Hexanoic acid, 2-ethyl-	149-57-5	144.00																		
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																		
Phthalic anhydride	85-44-9	148.00																	5.09	3
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																		
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																		
n-Amylcyclohexane	29949-27-7	154.00																		
Decanal	112-31-2	156.00	7.75	0.73	1.21	0.11					4.61	0.64	0.722	0.1						
Decane, 3-methyl-	13151-34-3	156.00																		
Decane, 4-methyl-	2847-72-5	156.00	2.42	0.73	0.379	0.11														
Nonane, 2,6-dimethyl-	17302-28-2	156.00																		
Undecane	1120-21-4	156.00	7.16	0.73	1.12	0.11	8.77	1.1	1.37	0.17	6.15	0.64	0.964	0.1	6.63	0.69	1.04	0.11		
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																		
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00					6.29	1.1	0.948	0.17	4.66	0.66	0.703	0.1	4.39	0.72	0.663	0.11		
Decane, 3,6-dimethyl-	17312-53-7	170.00																		
Dodecane	112-40-3	170.00	7.27	0.79	1.05	0.11	7.69	1.2	1.11	0.17	6.27	0.7	0.901	0.1	6.17	0.77	0.877	0.11		
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00													3.27	0.82	0.434	0.11		
Undecane, 2-methyl-	7045-71-8	170.00																		
Undecane, 3-methyl-	1002-43-3	170.00																		
Undecane, 4-methyl-	2980-69-0	170.00																		
Undecane, 5-methyl-	1632-70-8	170.00																		
Undecane, 6-methyl-	17302-33-9	170.00																		
Phenylmaleic anhydride	36122-35-7	174.00																		
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																		
Dodecane, 2-methyl-	1560-97-0	184.00																		
Dodecane, 4-methyl-	6117-97-1	184.00																		
Dodecane, 6-methyl-	6044-71-9	184.00																		
Tridecane	629-50-5	184.00	8.17	0.86	1.08	0.11	11.1	1.3	1.48	0.17	7.89	0.75	1.05	0.1	8.36	0.82	1.11	0.11		
Undecane, 2,6-dimethyl-	17301-23-4	184.00	3.79	0.86	0.503	0.11	4.9	1.3	0.651	0.17	3.37	0.75	0.448	0.1						
Undecane, 2,10-dimethyl-	17301-27-8	184.00																		
Undecane, 3,6-dimethyl-	17301-28-9	184.00																		
Cyclotetradecane	295-17-0	196.00									3.19	0.8	0.398	0.1						
Tetradecane	629-59-4	198.00	5.78	0.92	0.714	0.11	7.77	1.4	0.96	0.17	5.27	0.81	0.65	0.1	5.53	0.88	0.683	0.11		
Tridecane, 2-methyl-	1560-96-9	198.00																		
Tridecane, 3-methyl-	6418-41-3	198.00																		
Tridecane, 6-methyl-	13287-21-3	198.00																		
Tridecane, 7-methyl	26730-14-3	198.00	30.2	9.3	0.372	0.11	4.38	1.4	0.54	0.17	2.71	0.81	0.335	0.1						
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																		
Dodecanoic acid	143-07-7	200.00	6.24	0.93	0.763	0.11	11	1.4	1.34	0.17	4.7	0.82	0.575	0.1	6.44	0.89	0.787	0.11	30.6	4.1
2,4-Di-tert-butylphenol	96-76-4	206.00																	5.29	4.2
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																		
Pentadecane	629-62-9	212.00	4.17	0.99	0.48	0.11	7.37	1.5	0.85	0.17	4.48	0.87	0.517	0.1	3.91	0.94	0.45	0.11		
Tetradecane, 3-methyl-	18435-22-8	212.00																		
Diethyl Phthalate	84-66-2	222.00																		
Pentadecane, 7-methyl-	6165-40-8	226.00																		
Tridecane, 5-propyl-	55045-11-9	226.00																		
2,6,10-Trimethyltridecane	3891-99-4	226.00																		
Octadecane	593-45-3	254.00																		
Tributyl phosphate	126-73-8	266.00					190	1.8	17.4	0.17					201	1.2	18.5	0.11		
Triisobutyl phosphate	126-71-6	266.00					8.33	1.8	0.765	0.17					5.67	1.2	0.521	0.11		

Table 38. EPA TO-17 Target Compound Summary (May19, 2022, Repeat Mobil Jet II, MW 41-142)

EPA Method TO-17 - Tenax			**Thursday 5/19/2022, 12:19**				**Thursday 5/19/2022, 12:19**				**Thursday 5/19/2022, 15:46**				**Thursday 5/19/2022, 15: 46**				**Thursday 5/19/2022, 15:46**				**Thursday 5/19/2022, 15: 46**			
			Sample # 673919				**Sample # 673928**				**Sample # 673915**				**Sample # 673916**				**Sample # 673922**				**Sample # 673926**			
Fluid			**Baseline**				**Baseline**				**Mobil Jet II 5 cSt Std Oil**				**Mobil Jet II 5 cSt Std Oil**				**Mobil Jet II 5 cSt Std Oil**				**Mobil Jet II 5 cSt Std Oil**			
Bleed Temperature °C			**200 °C**				**200 °C**				**200 °C**				**200 °C**				**250 °C**				**250 °C**			
			Inlet				**Bleed**				**Inlet**				**Bleed**				**Inlet**				**Bleed**			
Analyte	**CAS Number**	**MW**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**
Acetonitrile	75-05-8	41.00																								
Methyl isocyanide	593-75-9	41.00																								
Formic acid	64-18-6	46.00																								
2-Propenal	107-02-8	56.00																								
Acetone	67-64-1	58.00									1.44	0.27	0.608	0.11												
Isopropyl Alcohol	67-63-0	60.00																								
1,4-Pentadiene	591-93-5	68.00																								
Butanal	123-72-8	72.00																								
3-Buten-2-one	78-94-4	70.00																								
Cyclopentane	287-92-3	70.00																								
Butane, 2-methyl-	78-78-4	72.00																								
Pentane	109-66-0	72.00																								
1-Butanol	71-36-3	74.00	5.03	0.38	1.66	0.13	4.47	0.32	1.48	0.1	3.23	0.34	1.07	0.11	3.48	0.33	1.15	0.11	3.37	0.32	1.11	0.1	5.98	0.33	1.97	0.11
2-Propanone, 1-hydroxy-	116-09-6	74.00									3.22	0.34	1.06	0.11												
2-Propanol, 2-methyl-	75-65-0	74.00																								
1,2-Propanediol	57-55-6	76.00													7.93	0.34	2.55	0.11								
Propylene Glycol	57-55-6	76.00					17.4	0.32	5.61	0.1													3.39	0.34	1.09	0.11
2-Ethylacrolein	922-63-4	84.00																								
1-Pentene, 2-methyl-	763-29-1	84.00																								
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																								
Pentane, 3-methyl-	96-14-0	86.00																								
1,3-Oxathiolane	2094-97-5	90.00																								
Phenol	108-95-2	94.00																								
Hexanal	66-25-1	100.00																								
Butanoic acid, 2-methyl-	116-53-0	102.00																								
1-Hexanol	111-27-3	102.00													3.08	0.45	0.737	0.11								
3-Methylpentan-1-ol	589-35-5	102.00																								
Benzaldehyde	100-52-7	106.00																								
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																								
Acetophenone	98-86-2	120.00																	2.47	0.51	0.504	0.1				
Benzeneacetaldehyde	122-78-1	120.00																								
Benzene, 1,2,3-trimethyl-	526-73-8	120.00																								
Benzene, 1,2,4-trimethyl-	95-63-6	120.00																								
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																								
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																								
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																								
Benzoic acid	65-85-0	122.00	7.68	0.62	1.54	0.13	4.34	0.52	0.87	0.1	6.88	0.57	1.38	0.11	5.65	0.54	1.13	0.11	9.31	0.52	1.87	0.1	5.2	0.54	1.04	0.11
Cycloalkane	64742-48-9	126.00																								
Cyclohexane, propyl-	1678-92-8	126.00																								
Azulene	275-51-4	128.00																								
Naphthalene	91-20-3	128.00	2.97	0.66	0.567	0.13																				
Octane, 2-methyl	3221-61-2	128.00																								
Octane, 3-methyl-	2216-33-3	128.00																								
Octane, 4-methyl-	2216-34-4	128.00																								
Formic acid, hexyl ester	629-33-4	130.00																					11.4	0.58	2.15	0.11
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																								
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																								
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																								
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																								
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00																								
2-Coumaranone	553-86-6	134.00																								
1-Decene	872-05-9	140.00									3.4	0.65	0.593	0.11												
1-Undecanol	112-42-5	140.00																	3.55	0.6	0.62	0.1				
2-Butenoic acid, butyl ester	7299-91-4	142.00																								

Table 39. EPA TO-17 Target Compound Summary (May19, 2022, Repeat Mobil Jet II, MW 142-266)

EPA Method TO-17 -Tenax			Thursday 5/19/2022, 12:19				Thursday 5/19/2022, 12:19				Thursday 5/19/2022, 15:46				Thursday 5/19/2022, 15:46				Thursday 5/19/2022, 15:46				Thursday 5/19/2022, 15:46			
			Sample # 673919				Sample # 673928				Sample #673915				Sample #673916				Sample #673922				Sample #673926			
Fluid			Baseline				Baseline				MobilJet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil			
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																								
Decane	124-18-5	142.00	6.37	0.73	1.1	0.13	4.86	0.61	0.837	0.1	6.87	0.66	1.18	0.11	6.4	0.63	1.1	0.11	6.85	0.61	1.18	0.1	6.62	0.63	1.14	0.11
Nonanal	124-19-6	142.00	6.55	0.73	1.13	0.13	5.01	0.61	0.862	0.1	13.5	0.66	2.32	0.11	5.1	0.63	0.878	0.11	7.4	0.61	1.27	0.1	4.1	0.63	0.706	0.11
Nonane, 4-methyl-	17301-94-9	142.00																								
Octane, 2,6-dimethyl-	2051-30-1	142.00																								
Hexanoic acid, 2-ethyl-	149-57-5	144.00																								
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																								
Phthalic anhydride	85-44-9	148.00																								
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																								
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																								
n-Amylcyclohexane	29949-27-7	154.00																								
Decanal	112-31-2	156.00	7.54	0.8	1.18	0.13	5.35	0.67	0.838	0.1	17.3	0.73	2.71	0.11	6.41	0.69	1	0.11	12.5	0.67	1.96	0.1	5.1	0.69	0.799	0.11
Decane, 3-methyl-	13151-34-3	156.00																								
Decane, 4-methyl-	2847-72-5	156.00																								
Nonane, 2,6-dimethyl-	17302-28-2	156.00																								
Undecane	1120-21-4	156.00	9.53	0.8	1.49	0.13	9.22	0.67	1.44	0.1	10.4	0.73	1.63	0.11	9.69	0.69	1.52	0.11	9.19	0.67	1.44	0.1	9.28	0.69	1.45	0.11
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																								
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	6.84	0.83	1.03	0.13	5.53	0.69	0.835	0.1	7.63	0.75	1.15	0.11					9.63	0.69	1.45	0.1	12.6	0.72	1.9	0.11
Decane, 3,6-dimethyl-	17312-53-7	170.00																								
Dodecane	112-40-3	170.00	14.8	0.87	2.13	0.13	9.39	0.73	1.35	0.1	12.3	0.79	1.77	0.11	11.5	0.76	1.65	0.11	11.4	0.73	1.64	0.1	11.3	0.76	1.62	0.11
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																								
Undecane, 2-methyl-	7045-71-8	170.00																								
Undecane, 3-methyl-	1002-43-3	170.00																								
Undecane, 4-methyl-	2980-69-0	170.00																								
Undecane, 5-methyl-	1632-70-8	170.00																								
Undecane, 6-methyl-	17302-33-9	170.00																								
Phenylmaleic anhydride	36122-35-7	174.00																								
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																								
Dodecane, 2-methyl-	1560-97-0	184.00																								
Dodecane, 4-methyl-	6117-97-1	184.00																								
Dodecane, 6-methyl-	6044-71-9	184.00	6.77	0.94	0.9	0.13									6.79	0.82	0.902	0.11					6.1	0.82	0.811	0.11
Tridecane	629-50-5	184.00	15.3	0.94	2.03	0.13	12.7	0.78	1.69	0.1	15.5	0.86	2.06	0.11	16.7	0.82	2.22	0.11	15.9	0.78	2.12	0.1	16.8	0.82	2.23	0.11
Undecane, 2,6-dimethyl-	17301-23-4	184.00					5.32	0.78	0.707	0.1	6.17	0.86	0.82	0.11	11.8	0.88	1.46	0.11	5.68	0.78	0.754	0.1				
Undecane, 2,10-dimethyl-	17301-27-8	184.00									5.04	0.86	0.669	0.11												
Undecane, 3,6-dimethyl-	17301-28-9	184.00																								
Cyclotetradecane	295-17-0	196.00	4.24	0.86	0.616	0.13																				
Tetradecane	629-59-4	198.00	11	1	1.36	0.13	8.6	0.84	1.06	0.1	10.4	0.92	1.28	0.11					11.1	0.84	1.38	0.1	11.6	0.88	1.43	0.11
Tridecane, 2-methyl-	1560-96-9	198.00	3.89	1	0.48	0.13																				
Tridecane, 3-methyl-	6418-41-3	198.00																								
Tridecane, 6-methyl-	13287-21-3	198.00																								
Tridecane, 7-methyl	26730-14-3	198.00					4.45	0.84	0.549	0.1					6.01	0.88	0.742	0.11	5.2	0.84	0.642	0.1	5.36	0.88	0.662	0.11
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																								
Dodecanoic acid	143-07-7	200.00	7.69	1	0.939	0.13	5.45	0.85	0.667	0.1	7.37	0.93	0.9	0.11	9.4	0.89	1.15	0.11	5.9	0.85	0.721	0.1	6.55	0.89	0.8	0.11
2,4-Di-tert-butylphenol	96-76-4	206.00																								
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																								
Pentadecane	629-62-9	212.00	6.06	1.1	0.698	0.13	6.42	0.9	0.74	0.1	7.97	0.99	0.918	0.11	11.6	0.94	1.34	0.11	6.67	0.9	0.769	0.1	7.49	0.94	0.863	0.11
Tetradecane, 3-methyl-	18435-22-8	212.00																	4.65	0.9	0.536	0.1				
Diethyl Phthalate	84-66-2	222.00																								
Pentadecane, 7-methyl-	6165-40-8	226.00					4.47	0.96	0.483	0.1									5.07	0.96	0.549	0.1	5.66	1	0.613	0.11
Tridecane, 5-propyl-	55045-11-9	226.00																								
2,6,10-Trimethyltridecane	3891-99-4	226.00	4.85	1.2	0.525	0.13																				
Octadecane	593-45-3	254.00																								
Tributyl phosphate	126-73-8	266.00					232	1.1	21.3	0.1					193	1.2	17.8	0.11					85.1	1.2	7.82	0.11
Triisobutyl phosphate	126-71-6	266.00					7.12	1.1	0.654	0.1					11.4	1.2	1.04	0.11					8.29	1.2	0.761	0.11

A summary of the EPA TO-17 TICS and report limits is presented in Table 40. More abundant compounds are bolded in Table 40 through Table 53.

- Table 40. Summary of TO-17 TICS (May 16, 2022, Eastman 2389, MW 41-142)
- Table 41. Summary of TO-17 TICS (May 16, 2022, Eastman 2389, MW 142-266)
- Table 42. Summary of TO-17 TICS (May 17, 2022, Mobil Jet II, MW 41-142)
- Table 43. Summary of TO-17 TICS (May 17, 2022, Mobil Jet II, MW 142-266)
- Table 44. Summary of TO-17 TICS (May 17, 2022, Mobil 387, MW 41-142)
- Table 45. Summary of TO-17 TICS (May 17, 2022, Mobil Jet 387, MW 142-266)
- Table 46. Summary of TO-17 TICS (May 18, 2022, Skydrol PE-5, MW 41-142)
- Table 47. Summary of TO-17 TICS (May 18, 2022, Skydrol PE-5, MW 142-266)
- Table 48. Summary of TO-17 TICS (May 18, 2022, HyJet IV-A+, MW 41-142)
- Table 49. Summary of TO-17 TICS (May 18, 2022, HyJet IV-A+, MW 142-266)
- Table 50. Summary of TO-17 TICS (May 19, 2022, Type I Deicing Fluid, MW 41-142)
- Table 51. Summary of TO-17 TICS (May 19, 2022, Type 1 Deicing Fluid, MW 142-266)
- Table 52. Summary of TO-17 TICS (May 19, 2022, Repeat Mobil Jet II, MW 41-142)
- Table 53. Summary of TO-17 TICS (May 19, 2022, Mobil Jet II, MW 142-266)

Table 40. Summary of TO-17 TICS (May 16, 2022, Eastman 2389, MW 41-142)

			Monday 5/16/2022, 17:15				Monday 5/16/2022, 14:50				Monday 5/16/2022, 14:50			
EPA Method TO-17 - Tenax			Sample #463638		Sample #463641		Sample # A035217				Sample # A035205			
Contaminant			n/a		n/a		Baseline				Baseline			
Bleed Temperature °C			n/a		n/a		200 °C				200 °C			
Sample Location			Field Blank		Ship Blank		Inlet				Bleed			
Analyte	CAS Number	MW	Result ng/tube	Report Limit ng/tube	Result ng/tube	Report Limit ng/tube	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
Acetonitrile	75-05-8	41.00	2.39	0.84			2.87	0.2	1.71	0.12				
Methyl isocyanide	593-75-9	41.00												
Formic acid	64-18-6	46.00												
2-Propenal	107-02-8	56.00												
Acetone	67-64-1	58.00	3.19	1.2	1.83	1.2					2.22	0.37	0.934	0.16
Isopropyl Alcohol	67-63-0	60.00												
1,4-Pentadiene	591-93-5	68.00												
Butanal	123-72-8	72.00												
3-Buten-2-one	78-94-4	70.00												
Cyclopentane	287-92-3	70.00												
Butane, 2-methyl-	78-78-4	72.00	3.89	1.5										
Pentane	109-66-0	72.00												
1-Butanol	71-36-3	74.00	3.79	1.5			7.18	0.36	2.37	0.12	8.57	0.47	2.83	0.16
2-Propanone, 1-hydroxy-	116-09-6	74.00												
2-Propanol, 2-methyl-	75-65-0	74.00												
1,2-Propanediol	57-55-6	76.00												
Propylene Glycol	57-55-6	76.00												
2-Ethylacrolein	922-63-4	84.00												
1-Pentene, 2-methyl-	763-29-1	84.00												
Oxetane, 3,3-dimethyl-	6921-35-3	86.00												
Pentane, 3-methyl-	96-14-0	86.00												
1,3-Oxathiolane	2094-97-5	90.00									7.41	0.58	2.01	0.16
Phenol	108-95-2	94.00												
Hexanal	66-25-1	100.00												
Butanoic acid, 2-methyl-	116-53-0	102.00												
1-Hexanol	111-27-3	102.00												
3-Methylpentan-1-ol	589-35-5	102.00												
Benzaldehyde	100-52-7	106.00	4.1	2.2	3.97	2.2								
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00												
Acetophenone	98-86-2	120.00												
Benzeneacetaldehyde	122-78-1	120.00												
Benzene, 1,2,3-trimethyl-	526-73-8	120.00												
Benzene, 1,2,4-trimethyl-	95-63-6	120.00					4.23	0.59	0.861	0.12				
Benzene, 1,3,5-trimethyl-	108-67-8	120.00												
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00									4.2	0.77	0.855	0.16
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00												
Benzoic acid	65-85-0	122.00	10.4	2.5	6.61	2.5								
Cycloalkane	64742-48-9	126.00												
Cyclohexane, propyl-	1678-92-8	126.00												
Azulene	275-51-4	128.00												
Naphthalene	91-20-3	128.00					4.64	0.62	0.885	0.12	4.77	0.82	0.911	0.16
Octane, 2-methyl	3221-61-2	128.00												
Octane, 3-methyl-	2216-33-3	128.00												
Octane, 4-methyl-	2216-34-4	128.00												
Formic acid, hexyl ester	629-33-4	130.00												
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00												
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00					4.54	0.65	0.829	0.12				
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00												
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00									5.11	0.86	0.932	0.16
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00												
2-Coumaranone	553-86-6	134.00												
1-Decene	872-05-9	140.00												
1-Undecanol	112-42-5	140.00												
2-Butenoic acid, butyl ester	7299-91-4	142.00												

Table 41. Summary of TO-17 TICS (May 16, 2022, Eastman 2389, MW 142-266)

			Monday 5/16/2022, 16:50				Monday 5/16/2022, 16:50				Monday 5/16/2022, 18:50				Monday 5/16/2022, 18:50			
EPA Method TO-17 - Tenax			Sample #463636				Sample #463637				Sample #A035254				Sample #463647			
Contaminant			Eastman 2389, 3 cSt Oil				Eastman 2389, 3 cSt Oil				Eastman 2389, 3 cSt Oil				Eastman 2389, 3 cSt Oil			
Bleed Temperature °C			200 °C				200 °C				260 °C				260 °C			
Sample Location			Inlet				Bleed				Inlet				Bleed			
Analyte	**CAS Number**	**MW**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																
Decane	124-18-5	142.00	12.9	0.66	2.22	0.11	13.1	0.73	2.26	0.13	17.5	0.66	3.02	0.11	12.8	0.69	2.21	0.12
Nonanal	124-19-6	142.00					4.41	0.73	0.76	0.13					4.39	0.69	0.756	0.12
Nonane, 4-methyl-	17301-94-9	142.00																
Octane, 2,6-dimethyl-	2051-30-1	142.00					5.54	0.73	0.95	0.13								
Hexanoic acid, 2-ethyl-	149-57-5	144.00	4.54	0.67	0.771	0.11	5.26	0.74	0.89	0.13								
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																
Phthalic anhydride	85-44-9	148.00	5.86	0.69	0.968	0.11												
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																
n-Amylcyclohexane	29949-27-7	154.00	4.86	0.72	0.771	0.11												
Decanal	112-31-2	156.00					4.46	0.8	0.7	0.13					6.34	0.76	0.994	0.12
Decane, 3-methyl-	13151-34-3	156.00																
Decane, 4-methyl-	2847-72-5	156.00	5.72	0.73	0.897	0.11	5.76	0.8	0.9	0.13	6.97	0.73	1.09	0.11	5.78	0.76	0.905	0.12
Nonane, 2,6-dimethyl-	17302-28-2	156.00																
Undecane	1120-21-4	156.00	18.6	0.73	2.92	0.11	24.6	0.8	3.85	0.13	17.8	0.73	2.79	0.11	13.8	0.76	2.15	0.12
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	12.7	0.75	1.92	0.11	12.1	0.83	1.83	0.13	8.79	0.75	1.33	0.11	9.93	0.79	1.5	0.12
Decane, 3,6-dimethyl-	17312-53-7	170.00																
Dodecane	112-40-3	170.00	18.4	0.62	3.35	0.11	24.1	0.87	3.46	0.13	19	0.79	2.74	0.11	18.7	0.83	2.7	0.12
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																
Undecane, 2-methyl-	7045-71-8	170.00					4.86	0.87	0.7	0.13								
Undecane, 3-methyl-	1002-43-3	170.00																
Undecane, 4-methyl-	2980-69-0	170.00																
Undecane, 5-methyl-	1632-70-8	170.00					5.93	0.87	0.85	0.13								
Undecane, 6-methyl-	17302-33-9	170.00									5	0.79	0.718	0.11				
Phenylmaleic anhydride	36122-35-7	174.00																
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																
Dodecane, 2-methyl-	1560-97-0	184.00					5.79	0.94	0.77	0.13								
Dodecane, 4-methyl-	6117-97-1	184.00																
Dodecane, 6-methyl-	6044-71-9	184.00					19.9	0.94	2.64	0.13	9.88	0.86	1.31	0.11				
Tridecane	629-50-5	184.00	20	0.86	2.66	0.11					16.8	0.86	2.24	0.11	17.1	0.9	2.27	0.12
Undecane, 2,6-dimethyl-	17301-23-4	184.00	13.1	0.86	1.74	0.11	12.9	0.94	1.71	0.13					10.1	0.9	1.35	0.12
Undecane, 2,10-dimethyl-	17301-27-8	184.00																
Undecane, 3,6-dimethyl-	17301-28-9	184.00																
Cyclotetradecane	295-17-0	196.00																
Tetradecane	629-59-4	198.00	11.5	0.92	1.41	0.11	11	1	1.36	0.13	10.5	0.92	1.29	0.11	10.2	0.96	1.26	0.12
Tridecane, 2-methyl-	1560-96-9	198.00																
Tridecane, 3-methyl-	6418-41-3	198.00																
Tridecane, 6-methyl-	13287-21-3	198.00																
Tridecane, 7-methyl	26730-14-3	198.00									6.14	0.92	0.758	0.11				
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																
Dodecanoic acid	143-07-7	200.00																
2,4-Di-tert-butylphenol	96-76-4	206.00																
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																
Pentadecane	629-62-9	212.00					6.13	1.1	0.71	0.13					8.62	1	0.993	0.12
Tetradecane, 3-methyl-	18435-22-8	212.00																
Diethyl Phthalate	84-66-2	222.00	6.65	1	0.732	0.11												
Pentadecane, 7-methyl-	6165-40-8	226.00																
Tridecane, 5-propyl-	55045-11-9	226.00																
2,6,10-Trimethyltridecane	3891-99-4	226.00																
Octadecane	593-45-3	254.00																
Tributyl phosphate	126-73-8	266.00																
Triisobutyl phosphate	126-71-6	266.00																

Table 42. Summary of TO-17 TICS (May 17, 2022, Mobil Jet II, MW 41-142)

EPA Method TO-17 - Tenax			Tuesday 5/17/2022, 8:50				Tuesday5/17/2022, 8:50				Tuesday 5/17/2022, 10:20				Tuesday5/17/2022, 11:57				Tuesday 5/17/2022, 11:57			
			Sample # 463634				Sample # 463631				Sample # 463643				Sample # 463624				Sample # 463623			
Fluid			Baseline				Baseline				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil			
Bleed Temperature °C			200 °C				200°C				200°C				250 °C				250°C			
			Inlet				Bleed				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
Acetonitrile	75-05-8	41.00																				
Methyl isocyanide	593-75-9	41.00																				
Formic acid	64-18-6	46.00																				
2-Propenal	107-02-8	56.00																				
Acetone	67-64-1	58.00																				
Isopropyl Alcohol	67-63-0	60.00													1.71	0.27	0.698	0.11				
1,4-Pentadiene	591-93-5	68.00																				
Butanal	123-72-8	72.00																				
3-Buten-2-one	78-94-4	70.00																				
Cyclopentane	287-92-3	70.00																				
Butane, 2-methyl-	78-78-4	72.00																				
Pentane	109-66-0	72.00																				
1-Butanol	71-36-3	74.00	40.2	0.42	13.3	0.14	7.05	0.38	2.33	0.13	7.82	0.38	2.58	0.13	36.3	0.33	12	0.11	5.92	0.34	1.95	0.11
2-Propanone, 1-hydroxy-	116-09-6	74.00																				
2-Propanol, 2-methyl-	75-65-0	74.00																				
1,2-Propanediol	57-55-6	76.00																				
Propylene Glycol	57-55-6	76.00																				
2-Ethylacrolein	922-63-4	84.00																				
1-Pentene, 2-methyl-	763-29-1	84.00																				
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																				
Pentane, 3-methyl-	96-14-0	86.00																				
1,3-Oxathiolane	2094-97-5	90.00																				
Phenol	108-95-2	94.00																				
Hexanal	66-25-1	100.00																				
Butanoic acid, 2-methyl-	116-53-0	102.00																	3.17	0.47	0.76	0.11
1-Hexanol	111-27-3	102.00																				
3-Methylpentan-1-ol	589-35-5	102.00																				
Benzaldehyde	100-52-7	106.00																				
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																				
Acetophenone	98-86-2	120.00																				
Benzeneacetaldehyde	122-78-1	120.00																				
Benzene, 1,2,3-trimethyl-	526-73-8	120.00																				
Benzene, 1,2,4-trimethyl-	95-63-6	120.00					1.96	0.61	0.398	0.13												
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																				
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																				
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																				
Benzoic acid	65-85-0	122.00	3.6	0.69	0.721	0.14									6.05	0.54	1.21	0.11				
Cycloalkane	64742-48-9	126.00																				
Cyclohexane, propyl-	1678-92-8	126.00																				
Azulene	275-51-4	128.00																				
Naphthalene	91-20-3	128.00	4.3	0.73	0.821	0.14	2.24	0.66	0.427	0.13	4.35	0.66	0.83	0.13	3.42	0.57	0.652	0.11	5.15	0.6	0.98	0.11
Octane, 2-methyl	3221-61-2	128.00																				
Octane, 3-methyl-	2216-33-3	128.00																				
Octane, 4-methyl-	2216-34-4	128.00																				
Formic acid, hexyl ester	629-33-4	130.00																				
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00	3.48	0.76	0.634	0.14																
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																				
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																				
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																				
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00									4.23	0.69	0.772	0.13								
2-Coumaranone	553-86-6	134.00																				
1-Decene	872-05-9	140.00																				
1-Undecanol	112-42-5	140.00																				
2-Butenoic acid, butyl ester	7299-91-4	142.00																				

Table 43. Summary of TO-17 TICS (May 17, 2022, Mobil Jet II, MW 142-266)

EPA Method TO-17 - Tenax			Tuesday 5/17/2022, 8:50				Tuesday5/17/2022, 8:50				Tuesday 5/17/2022, 10:20				Tuesday 5/17/2022, 11:57				Tuesday 5/17/2022, 11:57			
			Sample # 463634				Sample # 463631				Sample #463643				Sample # 463624				Sample # 463623			
Fluid			Baseline				Baseline				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil			
Bleed Temperature °C			200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																				
Decane	124-18-5	142.00	9.48	0.81	1.63	0.14	6.78	0.73	1.17	0.13	5.71	0.73	0.983	0.13	6.17	0.63	1.06	0.11	9.87	0.66	1.7	0.11
Nonanal	124-19-6	142.00	4.65	0.81	0.8	0.14	3.6	0.73	0.619	0.13					4.75	0.63	0.818	0.11				
Nonane, 4-methyl-	17301-94-9	142.00																	4.62	0.66	0.8	0.11
Octane, 2,6-dimethyl-	2051-30-1	142.00																				
Hexanoic acid, 2-ethyl-	149-57-5	144.00	4.29	0.82	0.728	0.14									3.64	0.64	0.618	0.11				
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																				
Phthalic anhydride	85-44-9	148.00																				
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																				
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00	4.54	0.86	0.73	0.14																
n-Amylcyclohexane	29949-27-7	154.00	4.94	0.88	0.783	0.14									3.78	0.69	0.6	0.11				
Decanal	112-31-2	156.00	4.2	0.89	0.658	0.14	3.15	0.8	0.494	0.13	5.54	0.8	0.868	0.13	4.66	0.69	0.731	0.11	7.66	0.73	1.2	0.11
Decane, 3-methyl-	13151-34-3	156.00					3.37	0.8	0.528	0.13					3.88	0.69	0.608	0.11				
Decane, 4-methyl-	2847-72-5	156.00	4.31	0.89	0.675	0.14	2.88	0.8	0.451	0.13												
Nonane, 2,6-dimethyl-	17302-28-2	156.00																				
Undecane	1120-21-4	156.00	17.3	0.89	2.71	0.14	10.9	0.8	1.71	0.13	13.3	0.8	2.08	0.13	14.2	0.69	2.23	0.11	14.7	0.73	2.3	0.11
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																				
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	11.1	0.92	1.67	0.14	6.26	0.83	0.944	0.13	10.7	0.93	1.43	0.13	10.7	0.72	1.61	0.11	9.58	0.75	1.44	0.11
Decane, 3,6-dimethyl-	17312-53-7	170.00													4.16	0.76	0.599	0.11				
Dodecane	112-40-3	170.00	18.4	0.97	2.65	0.14	11.9	0.87	1.71	0.13	21.9	0.87	3.14	0.13	17.1	0.76	2.46	0.11	30.5	0.79	4.38	0.11
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																				
Undecane, 2-methyl-	7045-71-8	170.00	4.34	0.97	0.624	0.14					4.42	0.87	0.635	0.13								
Undecane, 3-methyl-	1002-43-3	170.00																				
Undecane, 4-methyl-	2980-69-0	170.00					3.05	0.87	0.438	0.13	4.45	0.87	0.64	0.13					6.69	0.79	0.96	0.11
Undecane, 5-methyl-	1632-70-8	170.00	5.6	0.97	0.805	0.14																
Undecane, 6-methyl-	17302-33-9	170.00																				
Phenylmaleic anhydride	36122-35-7	174.00																				
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																				
Dodecane, 2-methyl-	1560-97-0	184.00					3	0.94	0.398	0.13					4.51	0.82	0.599	0.11				
Dodecane, 4-methyl-	6117-97-1	184.00																				
Dodecane, 6-methyl-	6044-71-9	184.00													9.26	0.82	1.23	0.11				
Tridecane	629-50-5	184.00	13.2	1.1	1.76	0.14	9.72	0.94	1.29	0.13	18.3	0.94	2.43	0.13	15.5	0.82	2.06	0.11	26.6	0.86	3.53	0.11
Undecane, 2,6-dimethyl-	17301-23-4	184.00					6.63	0.94	0.881	0.13	12.8	0.94	1.69	0.13								
Undecane, 2,10-dimethyl-	17301-27-8	184.00									6.04	0.94	0.802	0.13								
Undecane, 3,6-dimethyl-	17301-28-9	184.00	10.2	1.1	1.35	0.14													17.1	0.86	2.27	0.11
Cyclotetradecane	295-17-0	196.00																				
Tetradecane	629-59-4	198.00	7.5	1.1	0.926	0.14	5.52	1	0.682	0.13	11.7	1	1.44	0.13	8.75	0.88	1.08	0.11	12.8	0.92	1.58	0.11
Tridecane, 2-methyl-	1560-96-9	198.00																	6.29	0.92	0.78	0.11
Tridecane, 3-methyl-	6418-41-3	198.00																				
Tridecane, 6-methyl-	13287-21-3	198.00																				
Tridecane, 7-methyl	26730-14-3	198.00					3.89	1	0.48	0.13	8.31	1	1.03	0.13								
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																				
Dodecanoic acid	143-07-7	200.00																				
2,4-Di-tert-butylphenol	96-76-4	206.00																				
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																				
Pentadecane	629-62-9	212.00					4.14	1.1	0.477	0.13	7.1	1.1	0.819	0.13	5.98	0.94	0.689	0.11	7.49	0.99	0.86	0.11
Tetradecane, 3-methyl-	18435-22-8	212.00																				
Diethyl Phthalate	84-66-2	222.00																				
Pentadecane, 7-methyl-	6165-40-8	226.00																				
Tridecane, 5-propyl-	55045-11-9	226.00																				
2,6,10-Trimethyltridecane	3891-99-4	226.00																				
Octadecane	593-45-3	254.00																				
Tributyl phosphate	126-73-8	266.00																				
Triisobutyl phosphate	126-71-6	266.00																				

Table 44. Summary of TO-17 TICS (May 17, 2022, Mobil 387, MW 41-142)

EPA Method TO-17 - Tenax			Tuesday5/17/2022, 15:18				Tuesday 5/17/2022, 15:18				Tuesday 5/17/2022, 16:50				Tuesday 5/17/2022, 16:50				Tuesday 5/17/2022, 18:20				Tuesday 5/17/2022, 18:20				Wednesday 5/17/2022, 17:20	
			Sample #463648				Sample # 463639				Sample # 463626				Sample #463633				Sample # 463625				Sample # 463646				Sample # 463622	
Fluid			Baseline				Baseline				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				n/a	
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C				n/a	
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed				Field Blank	
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube
Acetonitrile	75-05-8	41.00																									1.11	0.84
Methyl isocyanide	593-75-9	41.00																										
Formic acid	64-18-6	46.00																										
2-Propenal	107-02-8	56.00																										
Acetone	67-64-1	58.00																									2.03	1.2
Isopropyl Alcohol	67-63-0	60.00																										
1,4-Pentadiene	591-93-5	68.00																										
Butanal	123-72-8	72.00																										
3-Buten-2-one	78-94-4	70.00																										
Cyclopentane	287-92-3	70.00																										
Butane, 2-methyl-	78-78-4	72.00																										
Pentane	109-66-0	72.00																										
1-Butanol	71-36-3	74.00	3.51	0.32	1.16	0.1	4.83	0.34	1.59	0.11	4.94	0.38	1.63	0.13	4.74	0.38	1.56	0.13	5.1	0.36	1.68	0.12					1.9	1.5
2-Propanone, 1-hydroxy-	116-09-6	74.00																										
2-Propanol, 2-methyl-	75-65-0	74.00																										
1,2-Propanediol	57-55-6	76.00																										
Propylene Glycol	57-55-6	76.00																										
2-Ethylacrolein	922-63-4	84.00																										
1-Pentene, 2-methyl-	763-29-1	84.00																										
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																										
Pentane, 3-methyl-	96-14-0	86.00																										
1,3-Oxathiolane	2094-97-5	90.00																										
Phenol	108-95-2	94.00																										
Hexanal	66-25-1	100.00																										
Butanoic acid, 2-methyl-	116-53-0	102.00																										
1-Hexanol	111-27-3	102.00																										
3-Methylpentan-1-ol	589-35-5	102.00																										
Benzaldehyde	100-52-7	106.00																									3.19	2.2
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																										
Acetophenone	98-86-2	120.00																										
Benzeneacetaldehyde	122-78-1	120.00																										
Benzene, 1,2,3-trimethyl-	526-73-8	120.00	4.15	0.51	0.846	0.1																						
Benzene, 1,2,4-trimethyl-	95-63-6	120.00									5.17	0.61	1.05	0.13														
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																										
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00	4.39	0.51	0.894	0.1																						
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																										
Benzoic acid	65-85-0	122.00	9.77	0.52	1.96	0.1					8.54	0.62	1.71	0.13					10.4	0.59	2.09	0.12					7.19	2.5
Cycloalkane	64742-48-9	126.00									4.51	0.64	0.875	0.13														
Cyclohexane, propyl-	1678-92-8	126.00	4.39	0.54	0.852	0.1					5.47	0.66	1.04	0.13	4.84	0.66	0.924	0.13	4.74	0.62	0.91	0.12	4.07	0.66	0.778	0.13		
Azulene	275-51-4	128.00																										
Naphthalene	91-20-3	128.00	5.18	0.55	0.989	0.1	5.15	0.6	0.982	0.11																		
Octane, 2-methyl	3221-61-2	128.00																										
Octane, 3-methyl-	2216-33-3	128.00																										
Octane, 4-methyl-	2216-34-4	128.00																										
Formic acid, hexyl ester	629-33-4	130.00																										
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																										
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																										
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																										
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																										
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00	5.14	0.57	0.937	0.1					5.4	0.69	0.985	0.13					5.4	0.65	0.99	0.12						
2-Coumaranone	553-86-6	134.00																										
1-Decene	872-05-9	140.00																										
1-Undecanol	112-42-5	140.00																										
2-Butenoic acid, butyl ester	7299-91-4	142.00																										

Table 45. Summary of TO-17 TICS (May 17, 2022, Mobil Jet 387, MW 142-266)

EPA Method TO-17 - Tenax			Tuesday 5/17/2022, 15:18				Tuesday 5/17/2022, 15:18				Tuesday 5/17/2022, 16:50				Tuesday 5/17/2022, 16:50				Tuesday 5/17/2022, 18:20				Tuesday 5/17/2022, 18:20				Wednesday 5/17/2022, 17:20	
			Sample #463648				Sample #463639				Sample #463626				Sample #463633				Sample #463625				Sample #463646				Sample #463622	
Fluid			Baseline				Baseline				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				Mobil Jet 387, 5 cSt HTS Oil				n/a	
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C				n/a	
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed				Field Blank	
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																										
Decane	124-18-5	142.00	15.4	0.61	2.65	0.1	14.3	0.66	2.45	0.11	18.3	0.73	3.15	0.13	10.6	0.73	1.83	0.13	7.88	0.69	1.36	0.12	8.08	0.73	1.39	0.13		
Nonanal	124-19-6	142.00																									3.77	2.9
Nonane, 4-methyl-	17301-94-9	142.00									5.22	0.73	0.898	0.13														
Octane, 2,6-dimethyl-	2051-30-1	142.00																										
Hexanoic acid, 2-ethyl-	149-57-5	144.00																										
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																										
Phthalic anhydride	85-44-9	148.00																										
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																										
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																										
n-Amylcyclohexane	29949-27-7	154.00																										
Decanal	112-31-2	156.00					8.75	0.73	1.37	0.11					6.88	0.8	1.08	0.13					7.56	0.8	1.18	0.13		
Decane, 3-methyl-	13151-34-3	156.00	6.35	0.67	0.995	0.1	5.57	0.73	0.872	0.11																		
Decane, 4-methyl-	2847-72-5	156.00									8.37	0.8	1.31	0.13														
Nonane, 2,6-dimethyl-	17302-28-2	156.00																										
Undecane	1120-21-4	156.00	16.9	0.67	2.64	0.1	15	0.73	2.34	0.11	20.2	0.8	3.17	0.13	13.2	0.8	2.06	0.13	13.5	0.76	2.11	0.12	10.3	0.8	1.62	0.13		
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																										
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	12.8	0.69	1.93	0.1	9.49	0.75	1.43	0.11	14.1	0.83	2.12	0.13	9.74	0.83	1.47	0.13	14.8	0.79	2.23	0.12	9	0.83	1.36	0.13		
Decane, 3,6-dimethyl-	17312-53-7	170.00																										
Dodecane	112-40-3	170.00	27	0.73	3.89	0.1	32.8	0.79	4.71	0.11	27.6	0.87	3.96	0.13	27.8	0.87	4	0.13	26.2	0.83	3.77	0.12	25.5	0.87	3.67	0.13		
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																										
Undecane, 2-methyl-	7045-71-8	170.00																	5.06	0.83	0.73	0.12						
Undecane, 3-methyl-	1002-43-3	170.00									7.47	0.87	1.07	0.13														
Undecane, 4-methyl-	2980-69-0	170.00					6.57	0.79	0.944	0.11																		
Undecane, 5-methyl-	1632-70-8	170.00																										
Undecane, 6-methyl-	17302-33-9	170.00																										
Phenylmaleic anhydride	36122-35-7	174.00																										
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																									6.53	3.7
Dodecane, 2-methyl-	1560-97-0	184.00					8.85	0.86	1.18	0.11					8.14	0.94	1.08	0.13										
Dodecane, 4-methyl-	6117-97-1	184.00																										
Dodecane, 6-methyl-	6044-71-9	184.00	15.5	0.78	2.05	0.1	17.9	0.86	2.38	0.11	15.6	0.94	2.07	0.13					13.5	0.9	1.79	0.12	13.5	0.94	1.79	0.13		
Tridecane	629-50-5	184.00	34.5	0.78	4.58	0.1	32.2	0.86	4.28	0.11	28.5	0.94	3.79	0.13	29.4	0.94	3.91	0.13	26.6	0.9	3.53	0.12	28	0.94	3.72	0.13		
Undecane, 2,6-dimethyl-	17301-23-4	184.00													15.6	0.94	2.07	0.13										
Undecane, 2,10-dimethyl-	17301-27-8	184.00	7.83	0.78	1.04	0.1																						
Undecane, 3,6-dimethyl-	17301-28-9	184.00																										
Cyclotetradecane	295-17-0	196.00																										
Tetradecane	629-59-4	198.00	16.8	0.84	2.08	0.1	17.6	0.99	2.03	0.11	16.8	1	2.08	0.13	18.7	1	2.31	0.13	15.1	0.96	1.87	0.12	14.8	1	1.82	0.13		
Tridecane, 2-methyl-	1560-96-9	198.00	9.18	0.84	1.13	0.1	7.99	0.92	0.987	0.11	7.34	1	0.906	0.13	7.62	1	0.941	0.13	6.71	0.96	0.83	0.12						
Tridecane, 3-methyl-	6418-41-3	198.00																	6.07	0.96	0.75	0.12						
Tridecane, 6-methyl-	13287-21-3	198.00									8.43	1	1.04	0.13	9.31	1	1.15	0.13										
Tridecane, 7-methyl	26730-14-3	198.00									12	1	1.48	0.13									11.9	1	1.47	0.13		
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																										
Dodecanoic acid	143-07-7	200.00																										
2,4-Di-tert-butylphenol	96-76-4	206.00																										
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																	6.8	1	0.78	0.12						
Pentadecane	629-62-9	212.00	11.6	0.9	1.34	0.1	9.97	0.99	1.15	0.11	11.9	1.1	1.38	0.13	14.1	1.1	1.63	0.13	11.3	1	1.3	0.12	8.08	1.1	0.931	0.13		
Tetradecane, 3-methyl-	18435-22-8	212.00																										
Diethyl Phthalate	84-66-2	222.00																										
Pentadecane, 7-methyl-	6165-40-8	226.00																	7.18	1.1	0.78	0.12						
Tridecane, 5-propyl-	55045-11-9	226.00													9.14	1.2	0.989	0.13										
2,6,10-Trimethyltridecane	3891-99-4	226.00																										
Octadecane	593-45-3	254.00																										
Tributyl phosphate	126-73-8	266.00																										
Triisobutyl phosphate	126-71-6	266.00																										

Table 46. Summary of TO-17 TICS (May 18, 2022, Skydrol PE-5, MW 41-142)

EPA Method TO-17 - Tenax			Wednesday 5/18/2022, 8:30				Wednesday 5/18/2022, 8:30				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55			
			Sample #463642				Sample # 463635				Sample #A035183				Sample # 463644				Sample #463650				Sample #A034773			
Fluid			Baseline				Baseline				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid			
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
Acetonitrile	75-05-8	41.00					1.1	0.28	0.66	0.17					2.71	0.21	1.62	0.13					1.02	0.26	0.607	0.16
Methyl isocyanide	593-75-9	41.00																								
Formic acid	64-18-6	46.00																								
2-Propenal	107-02-8	56.00																								
Acetone	67-64-1	58.00																					2.59	0.37	1.09	0.16
Isopropyl Alcohol	67-63-0	60.00																								
1,4-Pentadiene	591-93-5	68.00																								
Butanal	123-72-8	72.00																					2.1	0.46	0.714	0.16
3-Buten-2-one	78-94-4	70.00																					3.07	0.45	1.07	0.16
Cyclopentane	287-92-3	70.00													4.87	0.36	1.7	0.13								
Butane, 2-methyl-	78-78-4	72.00																								
Pentane	109-66-0	72.00																								
1-Butanol	71-36-3	74.00	4.94	0.58	1.63	0.19	5.06	0.51	1.67	0.17	5.88	0.34	1.94	0.11	14.4	0.38	4.75	0.13	6.03	0.36	1.99	0.12	19	0.47	6.28	0.16
2-Propanone, 1-hydroxy-	116-09-6	74.00																								
2-Propanol, 2-methyl-	75-65-0	74.00													2.07	0.38	0.682	0.13								
1,2-Propanediol	57-55-6	76.00																								
Propylene Glycol	57-55-6	76.00																								
2-Ethylacrolein	922-63-4	84.00																								
1-Pentene, 2-methyl-	763-29-1	84.00																								
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																								
Pentane, 3-methyl-	96-14-0	86.00													13.1	0.44	3.72	0.13								
1,3-Oxathiolane	2094-97-5	90.00																								
Phenol	108-95-2	94.00																								
Hexanal	66-25-1	100.00																								
Butanoic acid, 2-methyl-	116-53-0	102.00																								
1-Hexanol	111-27-3	102.00																								
3-Methylpentan-1-ol	589-35-5	102.00																								
Benzaldehyde	100-52-7	106.00																								
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00	2.04	0.88	0.446	0.19																				
Acetophenone	98-86-2	120.00	2.17	0.94	0.441	0.19	3.48	0.82	0.71	0.17																
Benzeneacetaldehyde	122-78-1	120.00																								
Benzene, 1,2,3-trimethyl-	526-73-8	120.00	1.87	0.94	0.381	0.19																				
Benzene, 1,2,4-trimethyl-	95-63-6	120.00																								
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																								
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																								
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																								
Benzoic acid	65-85-0	122.00	7.75	0.96	1.55	0.19	13.3	0.83	2.67	0.17	6.29	0.57	1.26	0.11					6.84	0.59	1.37	0.12				
Cycloalkane	64742-48-9	126.00																								
Cyclohexane, propyl-	1678-92-8	126.00	2	0.99	0.387	0.19																				
Azulene	275-51-4	128.00													3.42	0.66	0.652	0.13								
Naphthalene	91-20-3	128.00	2.14	1	0.409	0.19					2.19	0.6	0.418	0.11					1.98	0.62	0.378	0.12				
Octane, 2-methyl	3221-61-2	128.00																								
Octane, 3-methyl-	2216-33-3	128.00																								
Octane, 4-methyl-	2216-34-4	128.00																								
Formic acid, hexyl ester	629-33-4	130.00																								
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																								
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																								
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																								
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																								
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00																								
2-Coumaranone	553-86-6	134.00																								
1-Decene	872-05-9	140.00																								
1-Undecanol	112-42-5	140.00																								
2-Butenoic acid, butyl ester	7299-91-4	142.00																								

Table 47. Summary of TO-17 TICS (May 18, 2022, Skydrol PE-5, MW 142-266)

EPA Method TO-17 - Tenax			Wednesday 5/18/2022, 8:30				Wednesday 5/18/2022, 8:30				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55			
			Sample #463642				Sample #463635				Sample #A035183				Sample # 463644				Sample # 463650				Sample # A034773			
Fluid			Baseline				Baseline				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid				Skydrol PE-5 5000 Psi Hydraulic Fluid			
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																								
Decane	124-18-5	142.00	8.11	1.1	1.4	0.19	6.54	0.97	1.13	0.17	4.14	0.66	0.712	0.11					3.46	0.69	0.596	0.12	3.6	0.91	0.62	0.16
Nonanal	124-19-6	142.00	2.36	1.1	0.406	0.19	3.69	0.97	0.64	0.17					6.32	0.73	1.09	0.13	2.25	0.69	0.388	0.12				
Nonane, 4-methyl-	17301-94-9	142.00																								
Octane, 2,6-dimethyl-	2051-30-1	142.00																								
Hexanoicacid, 2-ethyl-	149-57-5	144.00	2.1	1.1	0.356	0.19																				
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																								
Phthalic anhydride	85-44-9	148.00																					4.02	0.95	0.663	0.16
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00									2.31	0.7	0.374	0.11												
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																								
n-Amylcyclohexane	29949-27-7	154.00																								
Decanal	112-31-2	156.00	2.68	1.2	0.419	0.19	3.38	1.1	0.53	0.17	3.76	0.73	0.589	0.11	6.84	0.8	1.07	0.13	2.11	0.76	0.33	0.12	3.03	1	0.475	0.16
Decane, 3-methyl-	13151-34-3	156.00					3.02	1.1	0.47	0.17																
Decane, 4-methyl-	2847-72-5	156.00	3.01	1.2	0.471	0.19	2.63	1.1	0.41	0.17																
Nonane, 2,6-dimethyl-	17302-28-2	156.00																								
Undecane	1120-21-4	156.00	8.48	1.2	1.33	0.19	7.95	1.1	1.25	0.17	7.09	0.73	1.11	0.11					6.63	0.76	1.04	0.12	6.32	1	0.991	0.16
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																	2.2	0.78	0.336	0.12				
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	6.65	1.3	1	0.19	5.82	1.1	0.88	0.17	6.74	0.75	1.02	0.11	7.25	0.83	1.09	0.13	6.42	0.79	0.969	0.12	5.15	1	0.777	0.16
Decane, 3,6-dimethyl-	17312-53-7	170.00																								
Dodecane	112-40-3	170.00	10.2	1.3	1.46	0.19	11	1.2	1.58	0.17	10.1	0.79	1.45	0.11	10.4	0.87	1.49	0.13	10.2	0.83	1.47	0.12	11.2	1.1	1.6	0.16
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00													21.8	0.87	3.13	0.13								
Undecane, 2-methyl-	7045-71-8	170.00	2.96	1.3	0.426	0.19																				
Undecane, 3-methyl-	1002-43-3	170.00																								
Undecane, 4-methyl-	2980-69-0	170.00																								
Undecane, 5-methyl-	1632-70-8	170.00																								
Undecane, 6-methyl-	17302-33-9	170.00																								
Phenylmaleic anhydride	36122-35-7	174.00					3.41	1.2	0.48	0.17	2.66	0.81	0.374	0.11												
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																								
Dodecane, 2-methyl-	1560-97-0	184.00																								
Dodecane, 4-methyl-	6117-97-1	184.00																								
Dodecane, 6-methyl-	6044-71-9	184.00									5.75	0.86	0.764	0.11	9.22	0.94	1.22	0.13								
Tridecane	629-50-5	184.00	10.6	1.5	1.41	0.19	11.3	1.3	1.51	0.17	11	0.86	1.47	0.11	13.9	0.94	1.85	0.13	11.1	0.9	1.48	0.12	13.2	1.2	1.76	0.16
Undecane, 2,6-dimethyl-	17301-23-4	184.00	5.82	1.5	0.773	0.19	6.05	1.3	0.8	0.17									5.4	0.9	0.718	0.12	5.05	1.2	0.671	0.16
Undecane, 2,10-dimethyl-	17301-27-8	184.00																								
Undecane, 3,6-dimethyl-	17301-28-9	184.00																								
Cyclotetradecane	295-17-0	196.00																								
Tetradecane	629-59-4	198.00	5.58	1.6	0.689	0.19	7.38	1.4	0.91	0.17	6.49	0.92	0.801	0.11	8.01	1	0.989	0.13	6.49	0.96	0.801	0.12	7.68	1.3	0.948	0.16
Tridecane, 2-methyl-	1560-96-9	198.00													5.22	1	0.644	0.13	2.72	0.96	0.336	0.12				
Tridecane, 3-methyl-	6418-41-3	198.00																	2.68	0.96	0.331	0.12				
Tridecane, 6-methyl-	13287-21-3	198.00																								
Tridecane, 7-methyl	26730-14-3	198.00					4.68	1.4	0.58	0.17	4.34	0.92	0.536	0.11					4.18	0.96	0.516	0.12	6.07	1.3	0.749	0.16
Dodecane, 2,5-dimethyl-	56292-65-0	198.00									3.87	0.92	0.478	0.11												
Dodecanoicacid	143-07-7	200.00																					5.27	1.3	0.644	0.16
2,4-Di-tert-butylphenol	96-76-4	206.00																								
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																								
Pentadecane	629-62-9	212.00									4.35	0.99	0.501	0.11	7.08	1.1	0.816	0.13	4.47	1	0.515	0.12	4.69	1.4	0.541	0.16
Tetradecane, 3-methyl-	18435-22-8	212.00																								
Diethyl Phthalate	84-66-2	222.00																					6.36	1.4	0.7	0.16
Pentadecane, 7-methyl-	6165-40-8	226.00																								
Tridecane, 5-propyl-	55045-11-9	226.00																								
2,6,10-Trimethyltridecane	3891-99-4	226.00																								
Octadecane	593-45-3	254.00																								
Tributyl phosphate	126-73-8	266.00																					23.6	1.7	2.17	0.16
Triisobutyl phosphate	126-71-6	266.00																								

Table 48. Summary of TO-17 TICS (May 18, 2022, HyJet IV-A+, MW 41-142)

EPA Method TO-17 - Tenax			**Wednesday 5/18/2022, 14:32**				**Wednesday 5/18/2022, 14:32**				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 17:00		Wednesday 5/18/2022,	
			Sample #A035167				**Sample #A035270**				Sample #Y59084				Sample #Y59070				Sample # 673918				Sample # A673917				Sample #673930		Sample # 673925	
Fluid			**Baseline**				**Baseline**				HyJet IV-A+ Type IV Hydraulic Fluid				yJet IV-A+ Type IV Hydraulic Fluid				yJet IV-A+ Type IV Hydraulic Flui				HyJet IV-A+ Type IV Hydraulic Fluid				n/a		n/a	
Bleed Temperature °C			**200 °C**				**200 °C**				200 °C				200 °C				250 °C				250 °C				n/a		n/a	
			Inlet				**Bleed**				Inlet				Bleed				Inlet				Bleed				Field Blank		Ship Blank	
Analyte	CAS Number	MW	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	**Result ppbv**	**Report Limit ppbv**	**Result µg/m3**	**Report Limit µg/m3**	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Repor t Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tub e	Result ng/tube	Report Limit ng/tube
Acetonitrile	75-05-8	41.00									1.13	0.2	0.676	0.12																
Methyl isocyanide	593-75-9	41.00																									1.31	0.84		
Formic acid	64-18-6	46.00													14.8	0.24	7.85	0.13												
2-Propenal	107-02-8	56.00																												
Acetone	67-64-1	58.00																												
Isopropyl Alcohol	67-63-0	60.00																												
1,4-Pentadiene	591-93-5	68.00																												
Butanal	123-72-8	72.00																												
3-Buten-2-one	78-94-4	70.00																					1.9	0.38	0.664	0.13				
Cyclopentane	287-92-3	70.00																												
Butane, 2-methyl-	78-78-4	72.00																												
Pentane	109-66-0	72.00																									1.62	1.5		
1-Butanol	71-36-3	74.00	5.3	0.4	1.75	0.13	5.21	0.42	1.72	0.14	5.76	0.36	1.9	0.12	9.76	0.38	3.22	0.13	4.11	0.36	1.36	0.12	14.3	0.4	4.71	0.13				
2-Propanone, 1-hydroxy-	116-09-6	74.00																											4.94	1.5
2-Propanol, 2-methyl-	75-65-0	74.00																												
1,2-Propanediol	57-55-6	76.00																												
Propylene Glycol	57-55-6	76.00																												
2-Ethylacrolein	922-63-4	84.00																												
1-Pentene, 2-methyl-	763-29-1	84.00																											2.34	1.7
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																												
Pentane, 3-methyl-	96-14-0	86.00																												
1,3-Oxathiolane	2094-97-5	90.00																												
Phenol	108-95-2	94.00																												
Hexanal	66-25-1	100.00																					2.81	0.54	0.687	0.13				
Butanoic acid, 2-methyl-	116-53-0	102.00																												
1-Hexanol	111-27-3	102.00													5.33	0.52	1.28	0.13												
3-Methylpentan-1-ol	589-35-5	102.00																					14	0.55	3.35	0.13				
Benzaldehyde	100-52-7	106.00																									3.75	2.2	3.43	2.2
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																												
Acetophenone	98-86-2	120.00									2.72	0.59	0.555	0.12	21.4	0.61	4.36	0.13									3.81	2.5	3.84	2.5
Benzeneacetaldehyde	122-78-1	120.00									2.15	0.59	0.438	0.12	7.91	0.61	1.61	0.13												
Benzene, 1,2,3-trimethyl-	526-73-8	120.00																												
Benzene, 1,2,4-trimethyl-	95-63-6	120.00																												
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																												
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																												
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																												
Benzoic acid	65-85-0	122.00	10.6	0.66	2.12	0.13	3.86	0.69	0.773	0.14	7.44	0.59	1.49	0.12	220	0.62	44.1	0.13	7.6	0.59	1.52	0.12	7.07	0.66	1.42	0.13	10.6	2.5	10.2	2.5
Cycloalkane	64742-48-9	126.00																												
Cyclohexane, propyl-	1678-92-8	126.00																												
Azulene	275-51-4	128.00																												
Naphthalene	91-20-3	128.00																												
Octane, 2-methyl	3221-61-2	128.00																												
Octane, 3-methyl-	2216-33-3	128.00																												
Octane, 4-methyl-	2216-34-4	128.00																												
Formic acid, hexyl ester	629-33-4	130.00																												
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																												
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																												
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																												
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																												
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00																												
2-Coumaranone	553-86-6	134.00													5.01	0.69	0.913	0.13												
1-Decene	872-05-9	140.00																									2.9	2.9		
1-Undecanol	112-42-5	140.00																												
2-Butenoic acid, butyl ester	7299-91-4	142.00					3.49	0.81	0.6	0.14																				

Table 49. Summary of TO-17 TICS (May 18, 2022, HyJet IV-A+, MW 142-266)

EPA Method TO-17 - Tenax			Wednesday 5/18/2022, 14:32				Wednesday 5/18/2022, 14:32				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 9:55				Wednesday 5/18/2022, 17:00		Wednesday 5/18/2022,	
			Sample #A035167				Sample #A035270				Sample #Y59084				Sample #Y59070				Sample #673918				Sample #A673917				Sample #673930		Sample #673925	
Fluid			Baseline				Baseline				HyJet IV-A+ Type IV Hydraulic Fluid				HyJet IV-A+ Type IV Hydraulic Flui				yJet IV-A+ Type IV Hydraulic Flui				HyJet IV-A+ Type IV Hydraulic Fluid				n/a		n/a	
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C				n/a		n/a	
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed				Field Blank		Ship Blank	
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube	Result ng/tube	Report Limit ng/tube
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																												
Decane	124-18-5	142.00					3.29	0.81	0.566	0.14	8.98	0.69	1.55	0.12	8.23	0.73	1.42	0.13	5.39	0.69	0.928	0.12	5.14	0.76	0.885	0.13				
Nonanal	124-19-6	142.00																	8.67	0.69	1.49	0.12	5.65	0.76	0.973	0.13				
Nonane, 4-methyl-	17301-94-9	142.00																												
Octane, 2,6-dimethyl-	2051-30-1	142.00																												
Hexanoic acid, 2-ethyl-	149-57-5	144.00																												
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00													4.06	0.76	0.67	0.13												
Phthalic anhydride	85-44-9	148.00																												
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																												
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																												
n-Amylcyclohexane	29949-27-7	154.00																												
Decanal	112-31-2	156.00					4.66	0.89	0.731	0.14									10.9	0.76	1.7	0.12	5.22	0.84	0.818	0.13				
Decane, 3-methyl-	13151-34-3	156.00																												
Decane, 4-methyl-	2847-72-5	156.00									2.76	0.76	0.433	0.12																
Nonane, 2,6-dimethyl-	17302-28-2	156.00																												
Undecane	1120-21-4	156.00	7.25	0.84	1.14	0.13	6.63	0.89	1.04	0.14	8.96	0.76	1.4	0.12	8.68	0.8	1.36	0.13	6.89	0.76	1.08	0.12	6.78	0.84	1.06	0.13				
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																												
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	8.01	0.87	1.21	0.13	7.11	0.92	1.07	0.14	6.92	0.79	1.04	0.12	7.31	0.83	1.1	0.13	7.49	0.79	1.13	0.12	7.05	0.87	1.06	0.13				
Decane, 3,6-dimethyl-	17312-53-7	170.00																												
Dodecane	112-40-3	170.00	13	0.92	1.87	0.13	12.4	0.97	1.78	0.14	12.5	0.83	1.79	0.12	12.9	0.87	1.86	0.13	11.4	0.83	1.63	0.12	10.2	0.92	1.46	0.13				
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																												
Undecane, 2-methyl-	7045-71-8	170.00																												
Undecane, 3-methyl-	1002-43-3	170.00																												
Undecane, 4-methyl-	2980-69-0	170.00																												
Undecane, 5-methyl-	1632-70-8	170.00																												
Undecane, 6-methyl-	17302-33-9	170.00																												
Phenylmaleic anhydride	36122-35-7	174.00																												
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																												
Dodecane, 2-methyl-	1560-97-0	184.00																												
Dodecane, 4-methyl-	6117-97-1	184.00									3.57	0.9	0.474	0.12																
Dodecane, 6-methyl-	6044-71-9	184.00	5.65	0.99	0.75	0.13	6.52	1.1	0.866	0.14	6.21	0.9	0.825	0.12	6.61	0.94	0.878	0.13	5.3	0.9	0.704	0.12	4.98	0.99	0.661	0.13				
Tridecane	629-50-5	184.00	18.5	0.99	2.46	0.13	18.1	1.1	2.4	0.14	16	0.9	2.12	0.12	18.9	0.94	2.51	0.13	15.2	0.9	2.02	0.12	16.6	0.99	2.21	0.13				
Undecane, 2,6-dimethyl-	17301-23-4	184.00																												
Undecane, 2,10-dimethyl-	17301-27-8	184.00																												
Undecane, 3,6-dimethyl-	17301-28-9	184.00																												
Cyclotetradecane	295-17-0	196.00																												
Tetradecane	629-59-4	198.00	17.6	1.1	2.17	0.13	10.7	1.1	1.32	0.14	10.6	0.96	1.3	0.12	11.7	1	1.45	0.13	11.2	0.96	1.38	0.12	11.3	1.1	1.39	0.13				
Tridecane, 2-methyl-	1560-96-9	198.00	8.34	1.1	1.03	0.13					4.13	0.96	0.51	0.12	5.16	1	0.637	0.13	4.55	0.96	0.562	0.12								
Tridecane, 3-methyl-	6418-41-3	198.00									3.76	0.96	0.464	0.12																
Tridecane, 6-methyl-	13287-21-3	198.00									4.29	0.96	0.529	0.12																
Tridecane, 7-methyl	26730-14-3	198.00					6.09	1.1	0.752	0.14	5.38	0.96	0.664	0.12	6.85	1	0.845	0.13	5.09	0.96	0.629	0.12	5.23	1.1	0.645	0.13				
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																												
Dodecanoic acid	143-07-7	200.00																	7.07	0.97	0.863	0.12	7.56	1.1	0.924	0.13	14.3	4.1	17.3	4.1
2,4-Di-tert-butylphenol	96-76-4	206.00																												
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00	6.81	1.1	0.785	0.13																								
Pentadecane	629-62-9	212.00	8.22	1.1	0.947	0.13	6.15	1.2	0.708	0.14	7.15	1	0.824	0.12	9.14	1.1	1.05	0.13	7.88	1	0.908	0.12	7.35	1.1	0.847	0.13				
Tetradecane, 3-methyl-	18435-22-8	212.00																												
Diethyl Phthalate	84-66-2	222.00	16.8	1.2	1.85	0.13																								
Pentadecane, 7-methyl-	6165-40-8	226.00																												
Tridecane, 5-propyl-	55045-11-9	226.00																												
2,6,10-Trimethyltridecane	3891-99-4	226.00																												
Octadecane	593-45-3	254.00	19.2	1.4	1.85	0.13																								
Tributyl phosphate	126-73-8	266.00					165	1.5	15.2	0.14					490	1.4	45	0.13					205	1.4	18.8	0.13				
Triisobutyl phosphate	126-71-6	266.00					95	1.5	8.73	0.14					22	1.4	2.02	0.13					18.1	1.4	1.67	0.13				

Table 50. Summary of TO-17 TICS (May 19, 2022, Type I Deicing Fluid, MW 41-142)

EPA Method TO-17 - Tenax			Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 11:22	
			Sample #673912				Sample #673914				Sample # 673929				Sample #673923				Sample #673927	
Fluid			Baseline				Baseline				Type 1 Deicing Fluid				Type 1 Deicing Fluid				n/a	
ature °C			200 °C				200 °C				200 °C				200 °C				n/a	
			Inlet				Bleed				Inlet				Bleed				Field Blank	
	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube
Acetonitrile	75-05-8	41.00																	3.61	0.84
Methyl isocyanide	593-75-9	41.00																		
Formic acid	64-18-6	46.00																		
2-Propenal	107-02-8	56.00																	1.77	1.1
Acetone	67-64-1	58.00	0.893	0.27	0.376	0.11													4.19	1.2
Isopropyl Alcohol	67-63-0	60.00																		
1,4-Pentadiene	591-93-5	68.00																	1.94	1.4
Butanal	123-72-8	72.00																		
3-Buten-2-one	78-94-4	70.00																		
Cyclopentane	287-92-3	70.00																		
Butane, 2-methyl-	78-78-4	72.00																		
Pentane	109-66-0	72.00																	3.74	1.5
1-Butanol	71-36-3	74.00	2.9	0.34	0.959	0.11	5.58	0.51	1.84	0.17	4.44	0.3	1.47	0.1	5.72	0.33	1.89	0.11		
2-Propanone, 1-hydroxy-	116-09-6	74.00													3.11	0.33	1.03	0.11		
2-Propanol, 2-methyl-	75-65-0	74.00																		
1,2-Propanediol	57-55-6	76.00													270	0.34	86.9	0.11	2.02	1.6
Propylene Glycol	57-55-6	76.00																		
2-Ethylacrolein	922-63-4	84.00																		
1-Pentene, 2-methyl-	763-29-1	84.00																	3.57	1.7
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																	3.37	1.8
Pentane, 3-methyl-	96-14-0	86.00																	3.59	1.8
1,3-Oxathiolane	2094-97-5	90.00																		
Phenol	108-95-2	94.00																	2.28	1.9
Hexanal	66-25-1	100.00																		
Butanoic acid, 2-methyl-	116-53-0	102.00																		
1-Hexanol	111-27-3	102.00																		
3-Methylpentan-1-ol	589-35-5	102.00																		
Benzaldehyde	100-52-7	106.00																	4.22	2.2
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																		
Acetophenone	98-86-2	120.00	1.9	0.56	0.388	0.11	3.06	0.82	0.624	0.17	1.8	0.49	0.366	0.1					4.35	2.5
Benzeneacetaldehyde	122-78-1	120.00																		
Benzene, 1,2,3-trimethyl-	526-73-8	120.00																		
Benzene, 1,2,4-trimethyl-	95-63-6	120.00																		
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																		
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																		
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																		
Benzoic acid	65-85-0	122.00	5.81	0.57	1.16	0.11	5.31	0.83	1.06	0.17	5.54	0.5	1.11	0.1	4.11	0.54	0.823	0.11	13.6	2.5
Cycloalkane	64742-48-9	126.00																		
Cyclohexane, propyl-	1678-92-8	126.00																		
Azulene	275-51-4	128.00																		
Naphthalene	91-20-3	128.00																		
Octane, 2-methyl	3221-61-2	128.00																		
Octane, 3-methyl-	2216-33-3	128.00																		
Octane, 4-methyl-	2216-34-4	128.00																		
Formic acid, hexyl ester	629-33-4	130.00																		
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																		
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																		
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																		
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																		
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00																		
2-Coumaranone	553-86-6	134.00																		
1-Decene	872-05-9	140.00																		
1-Undecanol	112-42-5	140.00																		
2-Butenoic acid, butyl ester	7299-91-4	142.00																		

Table 51. Summary of TO-17 TICS (May 19, 2022, Type 1 Deicing Fluid, MW 142-266)

EPA Method TO-17 -Tenax			Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 8:05				Thursday 5/19/2022, 11:22	
			Sample #673912				Sample #673914				Sample #673929				Sample #673923				Sample #673927	
Fluid			Baseline				Baseline				Type 1 Deicing Fluid				Type 1 Deicing Fluid				n/a	
ature °C			200 °C				200 °C				200 °C				200 °C				n/a	
			Inlet				Bleed				Inlet				Bleed				Field Blank	
	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ng/tube	Report Limit ng/tube
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																		
Decane	124-18-5	142.00	6.03	0.66	1.04	0.11	7.68	0.97	1.32	0.17	3.74	0.58	0.643	0.1	3.94	0.63	0.677	0.11		
Nonanal	124-19-6	142.00	7.44	0.66	1.28	0.11	3.73	0.97	0.642	0.17	4.36	0.58	0.751	0.1	3.5	0.63	0.602	0.11		
Nonane, 4-methyl-	17301-94-9	142.00																		
Octane, 2,6-dimethyl-	2051-30-1	142.00																		
Hexanoic acid, 2-ethyl-	149-57-5	144.00																		
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																		
Phthalic anhydride	85-44-9	148.00																	5.09	3
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																		
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																		
n-Amylcyclohexane	29949-27-7	154.00																		
Decanal	112-31-2	156.00	7.75	0.73	1.21	0.11					4.61	0.64	0.722	0.1						
Decane, 3-methyl-	13151-34-3	156.00																		
Decane, 4-methyl-	2847-72-5	156.00	2.42	0.73	0.379	0.11														
Nonane, 2,6-dimethyl-	17302-28-2	156.00																		
Undecane	1120-21-4	156.00	7.16	0.73	1.12	0.11	8.77	1.1	1.37	0.17	6.15	0.64	0.964	0.1	6.63	0.69	1.04	0.11		
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																		
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00					6.29	1.1	0.948	0.17	4.66	0.66	0.703	0.1	4.39	0.72	0.663	0.11		
Decane, 3,6-dimethyl-	17312-53-7	170.00																		
Dodecane	112-40-3	170.00	7.27	0.79	1.05	0.11	7.69	1.2	1.11	0.17	6.27	0.7	0.901	0.1	6.17	0.77	0.877	0.11		
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00													3.27	0.82	0.434	0.11		
Undecane, 2-methyl-	7045-71-8	170.00																		
Undecane, 3-methyl-	1002-43-3	170.00																		
Undecane, 4-methyl-	2980-69-0	170.00																		
Undecane, 5-methyl-	1632-70-8	170.00																		
Undecane, 6-methyl-	17302-33-9	170.00																		
Phenylmaleic anhydride	36122-35-7	174.00																		
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																		
Dodecane, 2-methyl-	1560-97-0	184.00																		
Dodecane, 4-methyl-	6117-97-1	184.00																		
Dodecane, 6-methyl-	6044-71-9	184.00																		
Tridecane	629-50-5	184.00	8.17	0.86	1.08	0.11	11.1	1.3	1.48	0.17	7.89	0.75	1.05	0.1	8.36	0.82	1.11	0.11		
Undecane, 2,6-dimethyl-	17301-23-4	184.00	3.79	0.86	0.503	0.11	4.9	1.3	0.651	0.17	3.37	0.75	0.448	0.1						
Undecane, 2,10-dimethyl-	17301-27-8	184.00																		
Undecane, 3,6-dimethyl-	17301-28-9	184.00																		
Cyclotetradecane	295-17-0	196.00									3.19	0.8	0.398	0.1						
Tetradecane	629-59-4	198.00	5.78	0.92	0.714	0.11	7.77	1.4	0.96	0.17	5.27	0.81	0.65	0.1	5.53	0.88	0.683	0.11		
Tridecane, 2-methyl-	1560-96-9	198.00																		
Tridecane, 3-methyl-	6418-41-3	198.00																		
Tridecane, 6-methyl-	13287-21-3	198.00																		
Tridecane, 7-methyl	26730-14-3	198.00	30.2	9.3	0.372	0.11	4.38	1.4	0.54	0.17	2.71	0.81	0.335	0.1						
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																		
Dodecanoic acid	143-07-7	200.00	6.24	0.93	0.763	0.11	11	1.4	1.34	0.17	4.7	0.82	0.575	0.1	6.44	0.89	0.787	0.11	30.6	4.1
2,4-Di-tert-butylphenol	96-76-4	206.00																	5.29	4.2
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																		
Pentadecane	629-62-9	212.00	4.17	0.99	0.48	0.11	7.37	1.5	0.85	0.17	4.48	0.87	0.517	0.1	3.91	0.94	0.45	0.11		
Tetradecane, 3-methyl-	18435-22-8	212.00																		
Diethyl Phthalate	84-66-2	222.00																		
Pentadecane, 7-methyl-	6165-40-8	226.00																		
Tridecane, 5-propyl-	55045-11-9	226.00																		
2,6,10-Trimethyltridecane	3891-99-4	226.00																		
Octadecane	593-45-3	254.00																		
Tributyl phosphate	126-73-8	266.00					190	1.8	17.4	0.17					201	1.2	18.5	0.11		
Triisobutyl phosphate	126-71-6	266.00					8.33	1.8	0.765	0.17					5.67	1.2	0.521	0.11		

Table 52. Summary of TO-17 TICS (May 19, 2022, Repeat Mobil Jet II, MW 41-142)

EPA Method TO-17 -Tenax			Thursday 5/19/2022, 12:19				Thursday 5/19/2022, 12:19				Thursday 5/19/2022, 15:46				Thursday 5/19/2022, 15:46				Thursday 5/19/2022, 15:46				Thursday 5/19/2022, 15:46			
			Sample# 673919				Sample# 673928				Sample # 673915				Sample # 673916				Sample# 673922				Sample# 673926			
Fluid			Baseline				Baseline				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil			
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
Acetonitrile	75-05-8	41.00																								
Methyl isocyanide	593-75-9	41.00																								
Formic acid	64-18-6	46.00																								
2-Propenal	107-02-8	56.00																								
Acetone	67-64-1	58.00									1.44	0.27	0.608	0.11												
Isopropyl Alcohol	67-63-0	60.00																								
1,4-Pentadiene	591-93-5	68.00																								
Butanal	123-72-8	72.00																								
3-Buten-2-one	78-94-4	70.00																								
Cyclopentane	287-92-3	70.00																								
Butane, 2-methyl-	78-78-4	72.00																								
Pentane	109-66-0	72.00																								
1-Butanol	71-36-3	74.00	5.03	0.38	1.66	0.13	4.47	0.32	1.48	0.1	3.23	0.34	1.07	0.11	3.48	0.33	1.15	0.11	3.37	0.32	1.11	0.1	5.98	0.33	1.97	0.11
2-Propanone, 1-hydroxy-	116-09-6	74.00									3.22	0.34	1.06	0.11												
2-Propanol, 2-methyl-	75-65-0	74.00																								
1,2-Propanediol	57-55-6	76.00													7.93	0.34	2.55	0.11								
Propylene Glycol	57-55-6	76.00					17.4	0.32	5.61	0.1													3.39	0.34	1.09	0.11
2-Ethylacrolein	922-63-4	84.00																								
1-Pentene, 2-methyl-	763-29-1	84.00																								
Oxetane, 3,3-dimethyl-	6921-35-3	86.00																								
Pentane, 3-methyl-	96-14-0	86.00																								
1,3-Oxathiolane	2094-97-6	90.00																								
Phenol	108-95-2	94.00																								
Hexanal	66-25-1	100.00																								
Butanoic acid, 2-methyl-	116-53-0	102.00																								
1-Hexanol	111-27-3	102.00													3.08	0.45	0.737	0.11								
3-Methylpentan-1-ol	589-35-5	102.00																								
Benzaldehyde	100-52-7	106.00																								
Cyclohexane, 1,1-dimethyl-	590-66-9	112.00																								
Acetophenone	98-86-2	120.00																	2.47	0.51	0.504	0.1				
Benzeneacetaldehyde	122-78-1	120.00																								
Benzene, 1,2,3-trimethyl-	526-73-8	120.00																								
Benzene, 1,2,4-trimethyl-	95-63-6	120.00																								
Benzene, 1,3,5-trimethyl-	108-67-8	120.00																								
Benzene, 1-ethyl-2-methyl-	611-14-3	120.00																								
Benzene, 1-ethyl-4-methyl-	622-96-8	120.00																								
Benzoic acid	65-85-0	122.00	7.68	0.62	1.54	0.13	4.34	0.52	0.87	0.1	6.88	0.57	1.38	0.11	5.65	0.54	1.13	0.11	9.31	0.52	1.87	0.1	5.2	0.54	1.04	0.11
Cycloalkane	64742-48-9	126.00																								
Cyclohexane, propyl-	1678-92-8	126.00																								
Azulene	275-51-4	128.00																								
Naphthalene	91-20-3	128.00	2.97	0.66	0.567	0.13																				
Octane, 2-methyl	3221-61-2	128.00																								
Octane, 3-methyl-	2216-33-3	128.00																								
Octane, 4-methyl-	2216-34-4	128.00																								
Formic acid, hexyl ester	629-33-4	130.00																					11.4	0.58	2.15	0.11
Benzene, 1,2,4,5-tetramethyl-	95-93-2	134.00																								
Benzene, 1-ethyl-3,5-dimethyl-	934-74-7	134.00																								
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	134.00																								
Benzene, 4-ethyl-1,2-dimethyl-	934-80-5	134.00																								
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	134.00																								
2-Coumaranone	553-86-6	134.00																								
1-Decene	872-05-9	140.00									3.4	0.65	0.593	0.11												
1-Undecanol	112-42-5	140.00																	3.55	0.6	0.62	0.1				
2-Butenoic acid, butyl ester	7299-91-4	142.00																								

Table 53. Summary of TO-17 TICS (May 19, 2022, Mobil Jet II, MW 142-266)

EPA Method TO-17 -Tenax			Thursday 5/19/2022, 12:19				Thursday 5/19/2022, 12:19				Thursday 5/19/2022, 15:46				Thursday 5/19/2022, 15:46				Thursday 5/19/2022, 15:46				Thursday 5/19/2022, 15:46			
			Sample# 673919				Sample# 673928				Sample # 673915				Sample # 673916				Sample# 673922				Sample# 673926			
Fluid			Baseline				Baseline				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil				Mobil Jet II 5 cSt Std Oil			
Bleed Temperature °C			200 °C				200 °C				200 °C				200 °C				250 °C				250 °C			
			Inlet				Bleed				Inlet				Bleed				Inlet				Bleed			
Analyte	CAS Number	MW	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3	Result ppbv	Report Limit ppbv	Result µg/m3	Report Limit µg/m3
2-Propenoic acid, 2-methyl-, butyl ester	97-88-1	142.00																								
Decane	124-18-5	142.00	6.37	0.73	1.1	0.13	4.86	0.61	0.837	0.1	6.87	0.66	1.18	0.11	6.4	0.63	1.1	0.11	6.85	0.61	1.18	0.1	6.62	0.63	1.14	0.11
Nonanal	124-19-6	142.00	6.55	0.73	1.13	0.13	5.01	0.61	0.862	0.1	13.5	0.66	2.32	0.11	5.1	0.63	0.878	0.11	7.4	0.61	1.27	0.1	4.1	0.63	0.706	0.11
Nonane, 4-methyl-	17301-94-9	142.00																								
Octane, 2,6-dimethyl-	2051-30-1	142.00																								
Hexanoic acid, 2-ethyl-	149-57-5	144.00																								
Benzaldehyde, 2,4,5-trimethyl-	5779-72-6	148.00																								
Phthalic anhydride	85-44-9	148.00																								
Oxime-, methoxy-phenyl-_	1000222-86-6	151.00																								
Naphthalene, decahydro-2-methyl-	2958-76-1	152.00																								
n-Amylcyclohexane	29949-27-7	154.00																								
Decanal	112-31-2	156.00	7.54	0.8	1.18	0.13	5.35	0.67	0.838	0.1	17.3	0.73	2.71	0.11	6.41	0.69	1	0.11	12.5	0.67	1.96	0.1	5.1	0.69	0.799	0.11
Decane, 3-methyl-	13151-34-3	156.00																								
Decane, 4-methyl-	2847-72-5	156.00																								
Nonane, 2,6-dimethyl-	17302-28-2	156.00																								
Undecane	1120-21-4	156.00	9.53	0.8	1.49	0.13	9.22	0.67	1.44	0.1	10.4	0.73	1.63	0.11	9.69	0.69	1.52	0.11	9.19	0.67	1.44	0.1	9.28	0.69	1.45	0.11
Naphthalene, 1,2,3,4-tetrahydro-2,7-dimethyl-	13065-07-1	160.00																								
Ethanol, 2-(2-butoxyethoxy)-	112-34-5	162.00	6.84	0.83	1.03	0.13	5.53	0.69	0.835	0.1	7.63	0.75	1.15	0.11					9.63	0.69	1.45	0.1	12.6	0.72	1.9	0.11
Decane, 3,6-dimethyl-	17312-53-7	170.00																								
Dodecane	112-40-3	170.00	14.8	0.87	2.13	0.13	9.39	0.73	1.35	0.1	12.3	0.79	1.77	0.11	11.5	0.76	1.65	0.11	11.4	0.73	1.64	0.1	11.3	0.76	1.62	0.11
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	170.00																								
Undecane, 2-methyl-	7045-71-8	170.00																								
Undecane, 3-methyl-	1002-43-3	170.00																								
Undecane, 4-methyl-	2980-69-0	170.00																								
Undecane, 5-methyl-	1632-70-8	170.00																								
Undecane, 6-methyl-	17302-33-9	170.00																								
Phenylmaleic anhydride	36122-35-7	174.00																								
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	180.00																								
Dodecane, 2-methyl-	1560-97-0	184.00																								
Dodecane, 4-methyl-	6117-97-1	184.00																								
Dodecane, 6-methyl-	6044-71-9	184.00	6.77	0.94	0.9	0.13									6.79	0.82	0.902	0.11					6.1	0.82	0.811	0.11
Tridecane	629-50-5	184.00	15.3	0.94	2.03	0.13	12.7	0.78	1.69	0.1	15.5	0.86	2.06	0.11	16.7	0.82	2.22	0.11	15.9	0.78	2.12	0.1	16.8	0.82	2.23	0.11
Undecane, 2,6-dimethyl-	17301-23-4	184.00					5.32	0.78	0.707	0.1	6.17	0.86	0.82	0.11	11.8	0.88	1.46	0.11	5.68	0.78	0.754	0.1				
Undecane, 2,10-dimethyl-	17301-27-8	184.00									5.04	0.86	0.669	0.11												
Undecane, 3,6-dimethyl-	17301-28-9	184.00																								
Cyclotetradecane	295-17-0	196.00	4.24	0.86	0.616	0.13																				
Tetradecane	629-59-4	198.00	11	1	1.36	0.13	8.6	0.84	1.06	0.1	10.4	0.92	1.28	0.11					11.1	0.84	1.38	0.1	11.6	0.88	1.43	0.11
Tridecane, 2-methyl-	1560-96-9	198.00	3.89	1	0.48	0.13																				
Tridecane, 3-methyl-	6418-41-3	198.00																								
Tridecane, 6-methyl-	13287-21-3	198.00																								
Tridecane, 7-methyl	26730-14-3	198.00					4.45	0.84	0.549	0.1					6.01	0.88	0.742	0.11	5.2	0.84	0.642	0.1	5.36	0.88	0.662	0.11
Dodecane, 2,5-dimethyl-	56292-65-0	198.00																								
Dodecanoic acid	143-07-7	200.00	7.69	1	0.939	0.13	5.45	0.85	0.667	0.1	7.37	0.93	0.9	0.11	9.4	0.89	1.15	0.11	5.9	0.85	0.721	0.1	6.55	0.89	0.8	0.11
2,4-Di-tert-butylphenol	96-76-4	206.00																								
Dodecane, 2,6,10-trimethyl-	3891-98-3	212.00																								
Pentadecane	629-62-9	212.00	6.06	1.1	0.698	0.13	6.42	0.9	0.74	0.1	7.97	0.99	0.918	0.11	11.6	0.94	1.34	0.11	6.67	0.9	0.769	0.1	7.49	0.94	0.863	0.11
Tetradecane, 3-methyl-	18435-22-8	212.00																	4.65	0.9	0.536	0.1				
Diethyl Phthalate	84-66-2	222.00																								
Pentadecane, 7-methyl-	6165-40-8	226.00					4.47	0.96	0.483	0.1									5.07	0.96	0.549	0.1	5.66	1	0.613	0.11
Tridecane, 5-propyl-	55045-11-9	226.00																								
2,6,10-Trimethyltridecane	3891-99-4	226.00	4.85	1.2	0.525	0.13																				
Octadecane	593-45-3	254.00																								
Tributyl phosphate	126-73-8	266.00					232	1.1	21.3	0.1					193	1.2	17.8	0.11					85.1	1.2	7.82	0.11
Triisobutyl phosphate	126-71-6	266.00					7.12	1.1	0.654	0.1					11.4	1.2	1.04	0.11					8.29	1.2	0.761	0.11

3.2.6 US Department of Energy Protective Action Criteria (PAC)

Select US Department of Energy Exposure Limits (Energy, 2023) for compounds reported using the EPA methods in this report are compiled in Appendix F, Figures F-1 and F-2. Figure F-1 contains values for a number of aldehydes and organic acids. Figure F-2 contains values for a series of organophosphate isomers. Table F-1 presents PAC information for Pentanoic Acid and Table F-2 presents PAC information for Heptanoic Acid.

3.2.7 Lessons learned from instrument sampling

- Do not turn off sensors between samples if they can collect continuous data.
- Accurately record events in event log and identify test conditions.
- Stay on test condition for a sufficient period to obtain replicate results.
- Make sure instruments are properly configured and that data is being recorded.
- Verify that the sensors are not over-range.

3.2.8 Lessons learned from laboratory chemical sampling

- Use full sample identification on the chain of custody, rather than brief description such as inlet and bleed. Simple descriptions are difficult to track in the final report.
- Pallflex® quartz filters, which are binder free, would have been preferred, but were not requested on the PO. For future measurements, KSU will specify Pallflex® filters, or order a box of Pallflex® filters. The EPA TO-13A procedure references the Whatman QM-A4 filters (EPA, 1999) used in this study, and have not changed the recommendation, even though they have published a study indicating there are more efficient filters available.

4 February 2022 American Airlines on-aircraft test

Kansas State University was invited by American Airlines and Pall to participate in an on-wing test of an A320 series aircraft in early February 2022. The KSU team had no control over the test plan and the test protocol to determine the olfactory threshold. However, the KSU team saw the invitation to participate in this study to obtain potentially useful data on the response of real time sensors to a realistic contaminant event on an airplane. A subset of the instruments used at the KSU engine test in May 2022 were utilized on-board the American Airlines aircraft.

4.1 Test setup

The aircraft information for the aircraft tested is provided in Table 54.

Table 54. Aircraft information for the on-aircraft test

Aircraft Information	
Registration:	N165US
Manufacturer Serial Number (MSN):	1431
Delivered:	2/22/2001
Total Ship Cycles:	25783
Total Ship Flight Hours:	67813.05

The Auxiliary Power Unit (APU) information for the aircraft tested is provided in Table 55.

Table 55. APU information for the on-aircraft test

APU Information	
Model:	Honeywell 131-9A
Serial Number:	P-6254
Date Installed:	3/6/2020
Time Since Installation:	9289.55
Time Since New (TSN):	18952.22

The ozone converter and ECS information for the aircraft tested is provided in Table 56.

Table 56. ECS component information for on-aircraft Test

	Part Number (PN)	**Serial Number (SN)**	**Installed**
BASF Original Equipment Manufacturer (OEM) Ozone Catalyst AeroCLEAN®	20499005	10230	2/10/2022
Flow Control Valve	1303A0000-04	1303-03460	12/31/2019
Primary Heat Exchanger	753C0000-02	81211-53921	3/31/2016
Main Heat Exchanger	754C0000-01	3219	3/31/2016

	Part Number (PN)	**Serial Number (SN)**	**Installed**
Air Cycle Machine (ACM)	1263A0000-03	2065	4/23/2010
Reheater	755C0000-01	81210-56993	3/31/2016
Condenser	756A0000-06	4153	11/26/2018
Water Extractor	747A0000-03	3143	2/22/2001
BASF OEM with AeroCOAT® VOC Catalyst	20499003-AP1	7084	2/10/2022
Flow Control Valve	1303A0000-04	1377	10/10/2017
Primary Heat Exchanger	753C0000-02	0753C00ES008614	3/31/2016
Main Heat Exchanger	754C0000-01	81212-56275	3/31/2016
ACM	1263A0000-03	4598	4/7/2016
Reheater	755C0000-01	4181	3/31/2016
Condenser	756A0000-06	2958	11/27/2018
Water Extractor	747A0000-03	3153	2/22/2001

American Airlines removed the in-service ozone converters and replaced them with a new ozone converter on the left side and a new ozone/VOC converter on the right side. An image of the ozone/VOC converter that was installed on the right side is shown in Figure 118.

Figure 118. BASF OEM AeroCoat® VOC /Ozone converter installed on the right side of the aircraft under test

They also replaced the aircraft HEPA recirculation filters with new carbon/HEPA recirculation filters. American Airlines allocated four hours to install and warm up sensors in the cabin prior to test, and 20 hours to test and remove all test equipment.

One turbine oil and one hydraulic fluid were injected pneumatically into the APU (Figure 120) and then sensed from lines connected to the bleed air start port below the aircraft. Bleed air was provided by APU only. The absolute and differential measurements obtained during this test provided information on performance of a variety of sensor types near the human olfactory thresholds of the test participants. Fluid injection rates were gradually increased until odor was observed. The olfaction level for turbine oil and deicing fluid injected into the ECS system through the APU inlet and measured downstream of the ozone and ozone/VOC converter are presented in Table 57.

Table 57. Minimum fluid injection rate to create odor at human olfactory level (HOL) of test personnel

Converter Type	**Turbine Oil**	**Deicing Fluid**
Ozone	3 ml/minute	8 ml/minute
VOC/Ozone	6 ml/minute	16 ml/minute

4.2 Sample transport

The position of test instruments relative to the air conditioning system is presented in Figure 119. The fluid injection table below the tail of the aircraft is shown in Figure 120. The air was sampled from the high pressure quick connect under the aircraft (Figure 121). Two refrigeration-grade copper lines with two-way isolation valves enabled the test team to minimize fluid cross contamination between fluid types (Figure 121). The bleed air sample entered a polycarbonate box lined with foil and electrically connected to ground to dissipate static charges (Figure 122). Air from the top of the mix manifold was routed through carbon loaded Teflon tubing to a box lined with foil and electrically grounded (Figure 123). The sampling boxes were ventilated to improve instrument response times by using a vane pump located outside of the aircraft (Figure 124). Pressures within the sampling boxes were monitored though digital manometers to ensure instruments were maintained near atmospheric pressure.

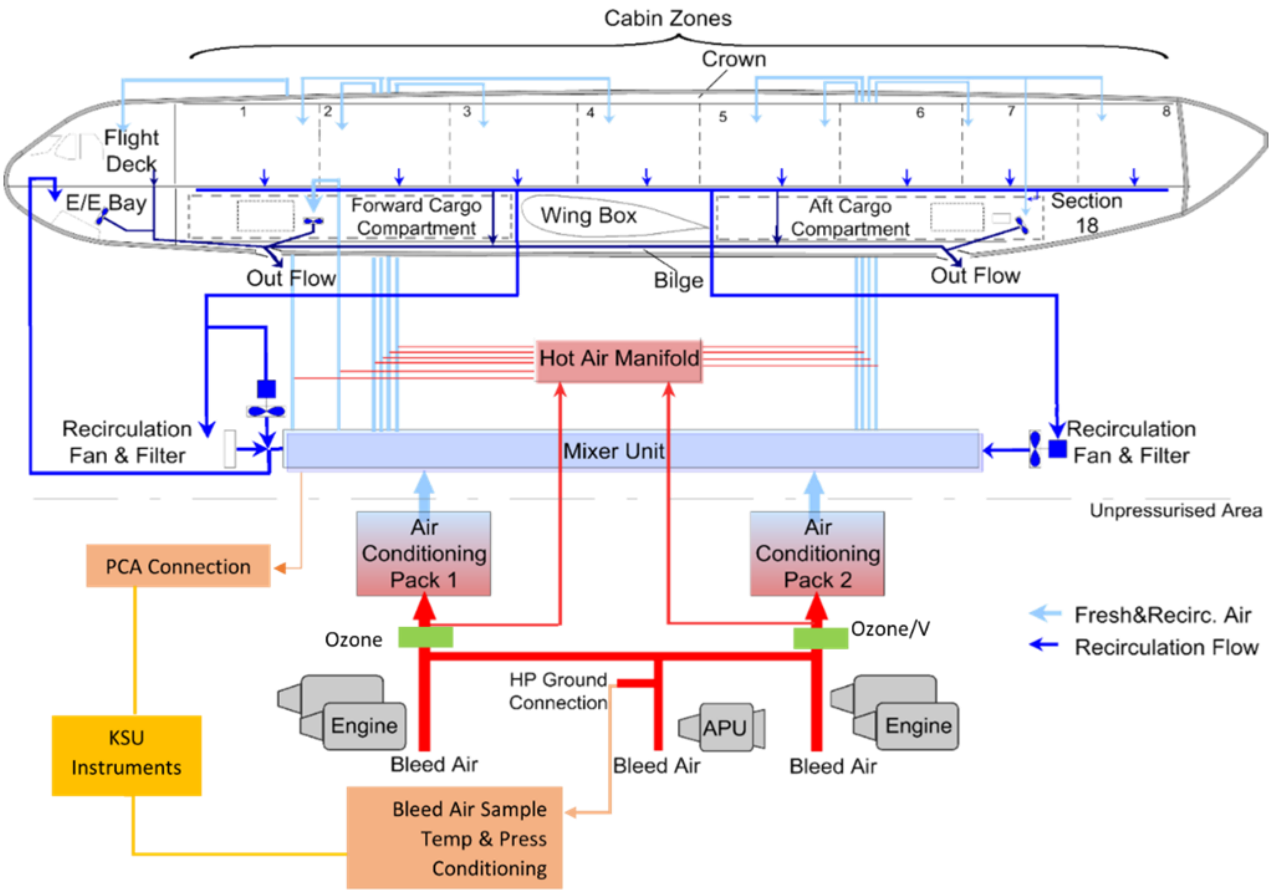


Figure 119. Test instrument location

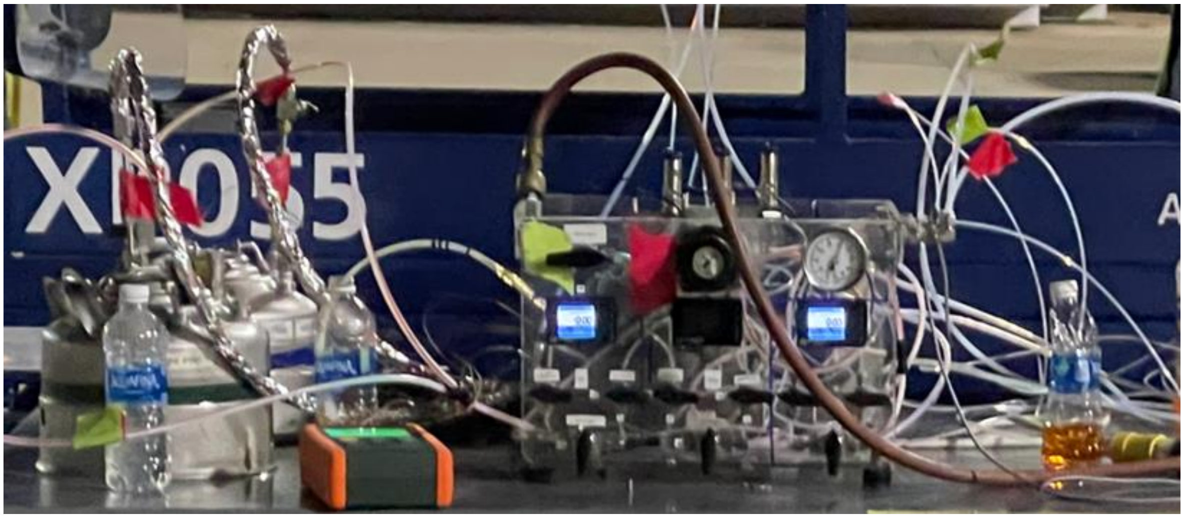


Figure 120. Pneumatic fluid injection system

Figure 121. HP sampling with dedicated lines for two fluid types

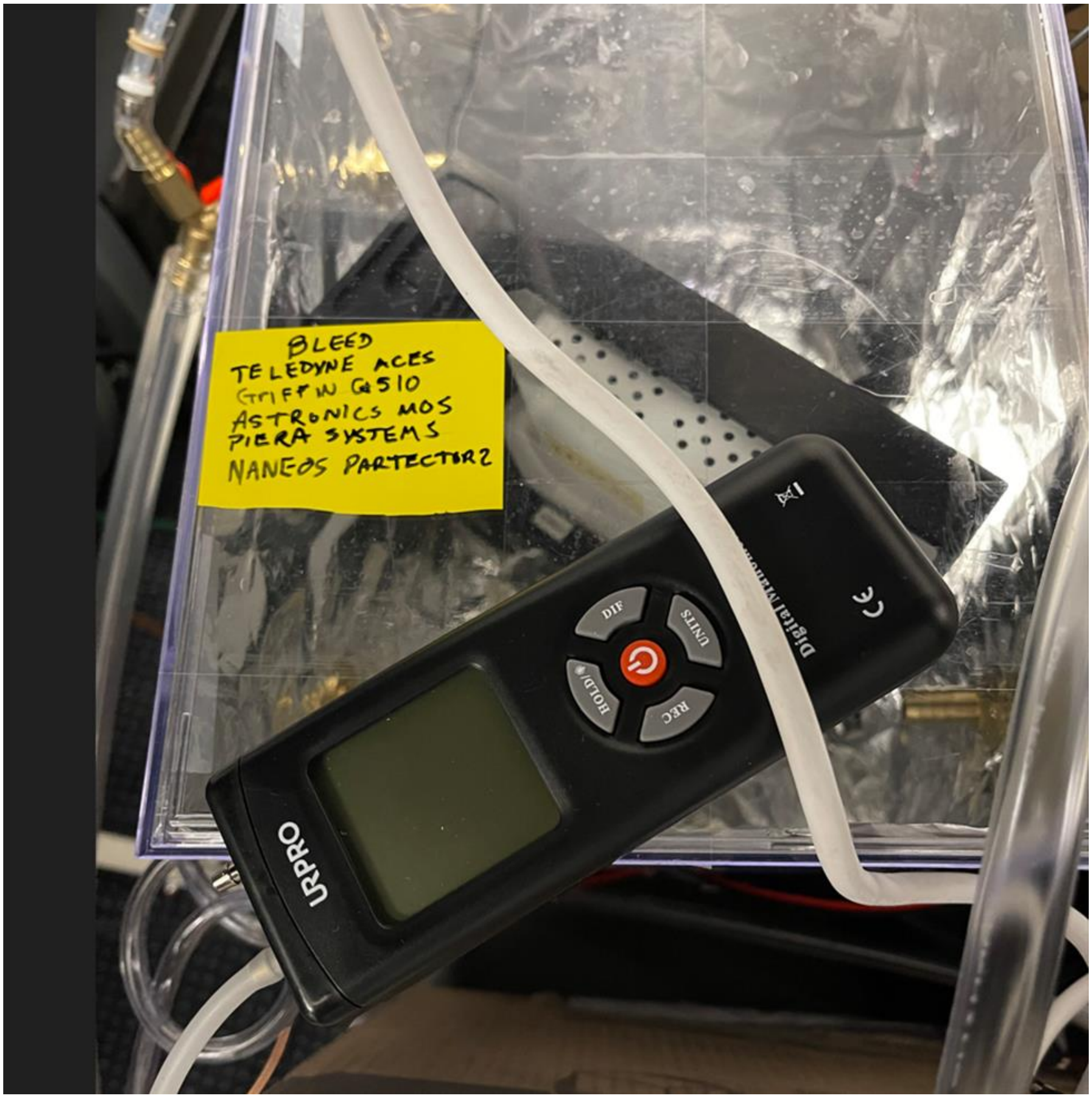


Figure 122. Bleed air sampling instruments

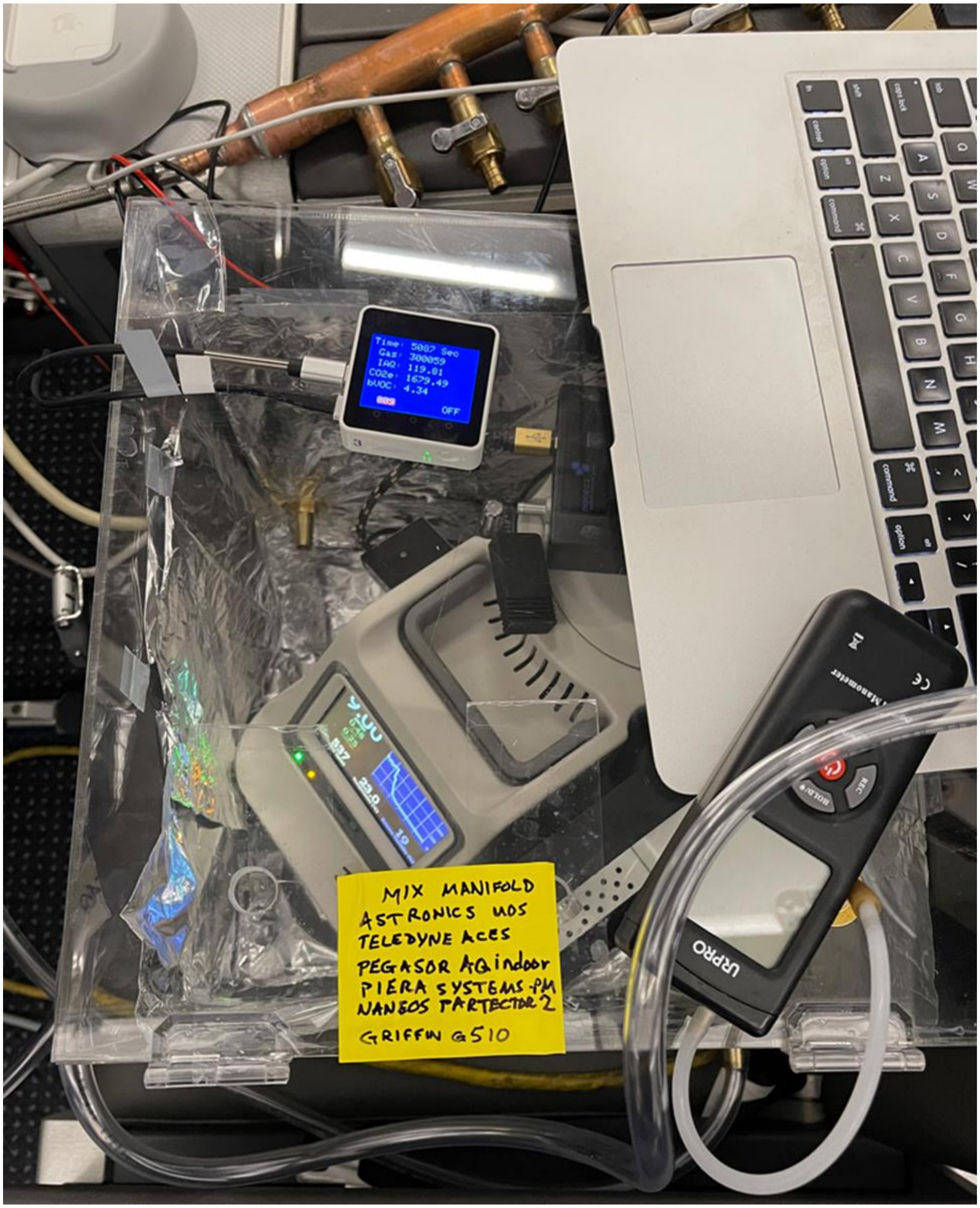


Figure 123. Mix manifold sampling instruments

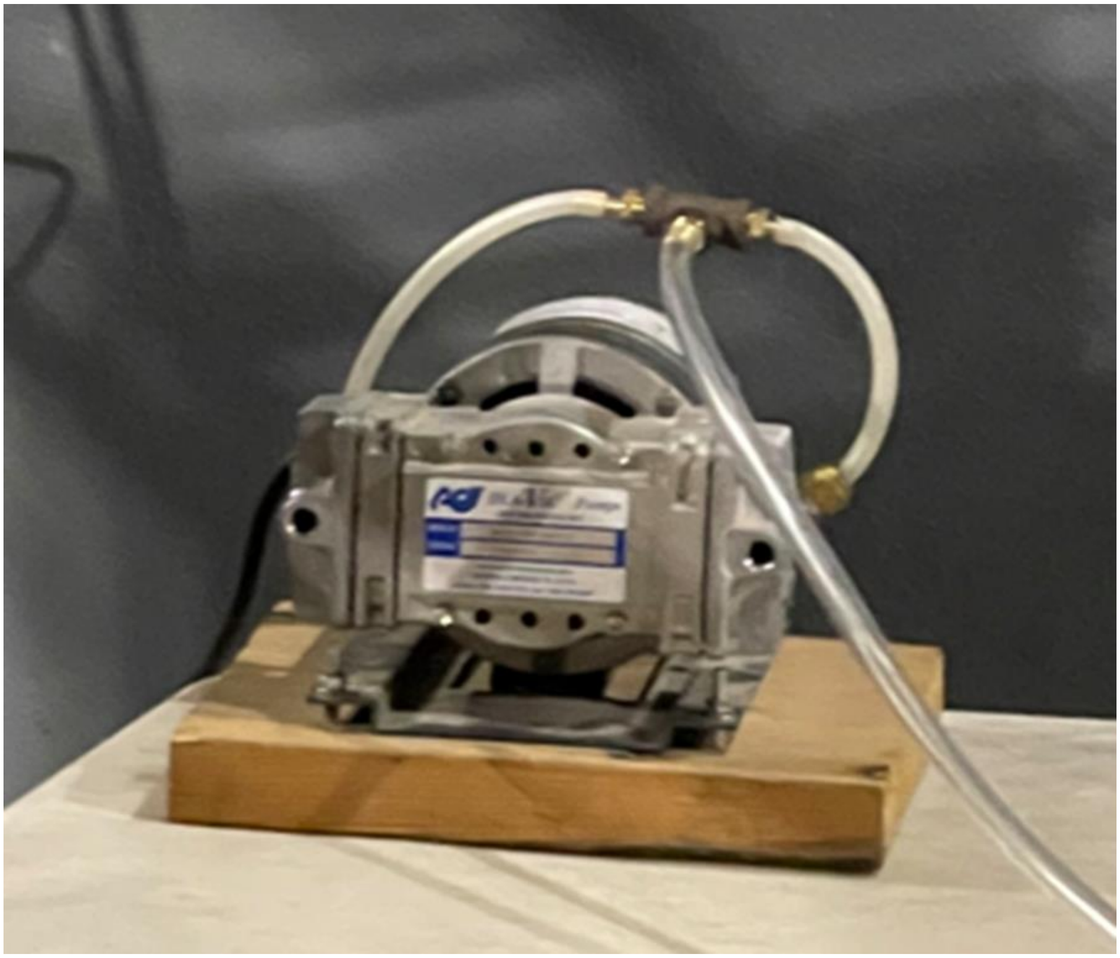


Figure 124. Sample box purge pump

4.3 American Airlines on-aircraft test plan

The KSU research team was invited to take sample measurements aboard an aircraft on which other system measurements were being conducted. The test plan called for the use of a standard ozone converter ahead of the left air conditioning pack and an ozone/VOC converter ahead of the right pack. The air conditioning packs were to be run at full cold (CCC means pack full cold), then normal (NNN means pack at normal operating temperature), and finally at full hot (HHH means pack full hot). Cabin air recirculation filters were changed out prior to the test. The contaminant dosing quantity was established by slowly increasing dosing quantity until odor was detected through Human Olfactory Level (HOL). A second dosing level was then established at twice the HOL (Table 58). The on-aircraft draft test plan is presented in Table 59. The quantity of oil entering the ECS was less than the dosing level since at least two thirds of the ingested oil passes through the engine and out the exhaust.

Table 58. Fluid injection rate HOL and 2HOL

Converter Type	**Turbine Oil HOL**	**Turbine Oil 2 X HOL**	**Deicing Fluid HOL**	**Deicing Fluid 2X HOL**
Ozone	3 ml/minute	6 ml/minute	8 ml/minute	16 ml/minute
Ozone/VOC	6 ml/minute	12 ml/minute	16 ml/minute	32 ml/minute

Table 59. Draft on-aircraft test plan

Estimated duration	**Planned Time (EST)**	**Planned Time (UTC)**	**Actual Time (EST)**	**Actual Time (UTC)**	**Test/Task**	Fluid Injection Rate	**Bleed, Mix manifold, and Gasper supply sample**
0	2/11/2022 6:05	2/11/2022 11:05	2/10/2022 23:06	2/11/2022 4:06	Start VOC Filter Test		
30	2/11/2022 6:35	2/11/2022 11:35			Background NNN	Standard Ozone Converter Deicing Fluid VOC	
10	2/11/2022 6:45	2/11/2022 11:45			Background CCC		
10	2/11/2022 6:55	2/11/2022 11:55			Background HHH		
10	2/11/2022 7:05	2/11/2022 12:05			Background NNN		g
8	2/11/2022 7:13	2/11/2022 12:13			Deicing Fluid @ HOL	8 ml/minute	g
8	2/11/2022 7:21	2/11/2022 12:21			Deicing Fluid 2x HOL	16 ml/minute	g
8	2/11/2022 7:29	2/11/2022 12:29			Classification Time		
30	2/11/2022 7:59	2/11/2022 12:59			Background NNN	Ozone/VOC Converter VOC	
10	2/11/2022 8:09	2/11/2022 13:09			Background CCC		
10	2/11/2022 8:19	2/11/2022 13:19			Background HHH		
10	2/11/2022 8:29	2/11/2022 13:29			Background NNN		g
8	2/11/2022 8:37	2/11/2022 13:37			Deicing Fluid HOL	16 ml/minute	g

Estimated duration	Planned Time (EST)	Planned Time (UTC)	Actual Time (EST)	Actual Time (UTC)	Test/Task	Fluid Injection Rate	Bleed, Mix manifold, and Gasper supply sample
8	2/11/2022 8:45	2/11/2022 13:45			Deicing Fluid 2x HOL	32 ml/minute	g
8	2/11/2022 8:53	2/11/2022 13:53			Classification Time		
10	2/11/2022 9:03	2/11/2022 14:03			Clean CCC		
10	2/11/2022 9:13	2/11/2022 14:13			Clean HHH		
10	2/11/2022 9:23	2/11/2022 14:23			Clean NNN		
30	2/11/2022 9:53	2/11/2022 14:53			Background NNN	Standard Ozone Converter OIL (Cabin Air Quality Sensor (CAQS)	
10	2/11/2022 10:03	2/11/2022 15:03			Background CCC		
10	2/11/2022 10:13	2/11/2022 15:13			Background HHH		
10	2/11/2022 10:23	2/11/2022 15:23			Background NNN		g
8	2/11/2022 10:31	2/11/2022 15:31			Oil HOL	8 ml/minute	g
8	2/11/2022 10:39	2/11/2022 15:39			Oil 2 xHOL	16 ml/minute	g
8	2/11/2022 10:47	2/11/2022 15:47			Classification Time		
30	2/11/2022 11:17	2/11/2022 16:17			Background NNN	Ozone/VOC Converter CAQS	
10	2/11/2022 11:27	2/11/2022 16:27			Background CCC		
10	2/11/2022 11:37	2/11/2022 16:37			Background HHH		
10	2/11/2022 11:47	2/11/2022 16:47			Background NNN		g
8	2/11/2022 11:55	2/11/2022 16:55			Oil HOL	3 ml/minute	g
8	2/11/2022 12:03	2/11/2022 17:03			Oil 2 x HOL	6 ml/minute	g
8	2/11/2022 12:11	2/11/2022 17:11			Classification Time		
10	2/11/2022 12:21	2/11/2022 17:21			Clean CCC		

Estimated duration	**Planned Time (EST)**	**Planned Time (UTC)**	**Actual Time (EST)**	**Actual Time (UTC)**	**Test/Task**	Fluid Injection Rate	**Bleed, Mix manifold, and Gasper supply sample**
10	2/11/2022 12:31	2/11/2022 17:31			Clean HHH	🟧	
10	2/11/2022 12:41	2/11/2022 17:41			Clean NNN	🟧	
120	2/11/2022 14:41	2/11/2022 19:41			Remove all kit & box/clean up	🟪	

4.4 Test instruments

4.4.1 Teledyne Controls - ACES® Sensor Suite

Teledyne controls provided two Aircraft Cabin Environment Sensors (ACES) which provided particulate and gas measurements for a range of potential gas contaminants. In addition, ACES gas sensors included a VOC photoionization sensor, a non-dispersive infrared sensor for carbon dioxide, an oxygen sensor, an electrochemical carbon monoxide sensor, an electrochemical hydrogen sulfide sensor, and an electrochemical nitrogen dioxide sensor.

4.4.2 TSI QTRAK-XP®

TSI provided a QTRAX-XP sensor suite that measured particulate matter (PM) from 0.3 microns to 10 microns diameter. In addition, gas sensors included a VOC photoionization sensor, a non-dispersive infrared sensor for carbon dioxide, an electrochemical carbon monoxide sensor, an electrochemical nitric oxide sensor, an ozone sensor, and a formaldehyde sensor.

4.4.3 Teledyne FLIR- Griffin G510® Portable GC/Mass Spectrometer

Teledyne FLIR provided a Griffin G510 which is used by first responders to assess potential environmental exposure contaminants. The G510 cycle time was limited by the amount of time required for the instrument to stabilize after each sample, so it was necessary to utilize Tedlar ® sample bags to capture sample and perform post analysis of the samples.

4.4.4 Astronics® MOS

Astronics® provided metal oxide diffusion type sensors to help sense VOC that might be present from the injected contaminants.

4.4.5 Piera Systems Red Laser PM Sensor

Kansas State University provided Piera Systems Model 7100Particle Matter sensors that measure micron size particle matter. The PM sensor reports over several size ranges. This report evaluated the total and differential 0.3-0.5-micron range, where most micron size particles are present.

4.4.6 Naneos Partector II – Corona Discharge UFP Sensor

CH Technologies and Naneos provided Naneos Partector II units that measured ultrafine particles in a range of 10 to 1000 nanometers.

4.4.7 Pegasor AQIndoor®- Corona Discharge UFP Sensor

Delta-Phase and Pegasor provided a Pegasor AQIndoor® for utilization in the system. The Pegasor AQIndoor® measures nanoparticles in a size range of 10 nanometers to 1 micron and carbon dioxide. The AQIndoor® is no longer produced and is being replaced by an instrument that has particle only measurement capabilities.

4.5 Test results

4.5.1 Sample location limitations

The sample locations that were available for this test were selected because they did not require a major modification to the aircraft. The result of this limitation is that no samples were acquired at the ozone converter exit. Samples acquired at the ozone converter inlet enable us to gain an idea of constituents and concentrations entering the ozone and VOC/ozone converters and passing through the air conditioning packs to the mix manifold, where they are mixed with recirculated air when the recirculation system is operating.

Several chemical species sensors, namely formaldehyde and nitric oxide, were only available on one instrument and therefore located at the bleed air sample location on day 1, and on the mix manifold location on day 2. Test results are summarized for samples during APU ingestion of deicing fluid in Figure 125 and for turbine oil in Figure 126.

In addition to not being able to evaluate the effect ozone vs. VOC/ozone converter, the duration of fluid injection was not consistent throughout the test, and there is great likelihood that fluid concentration had not stabilized prior to moving to the next test condition, based on testing experience during the earlier tests in this study.

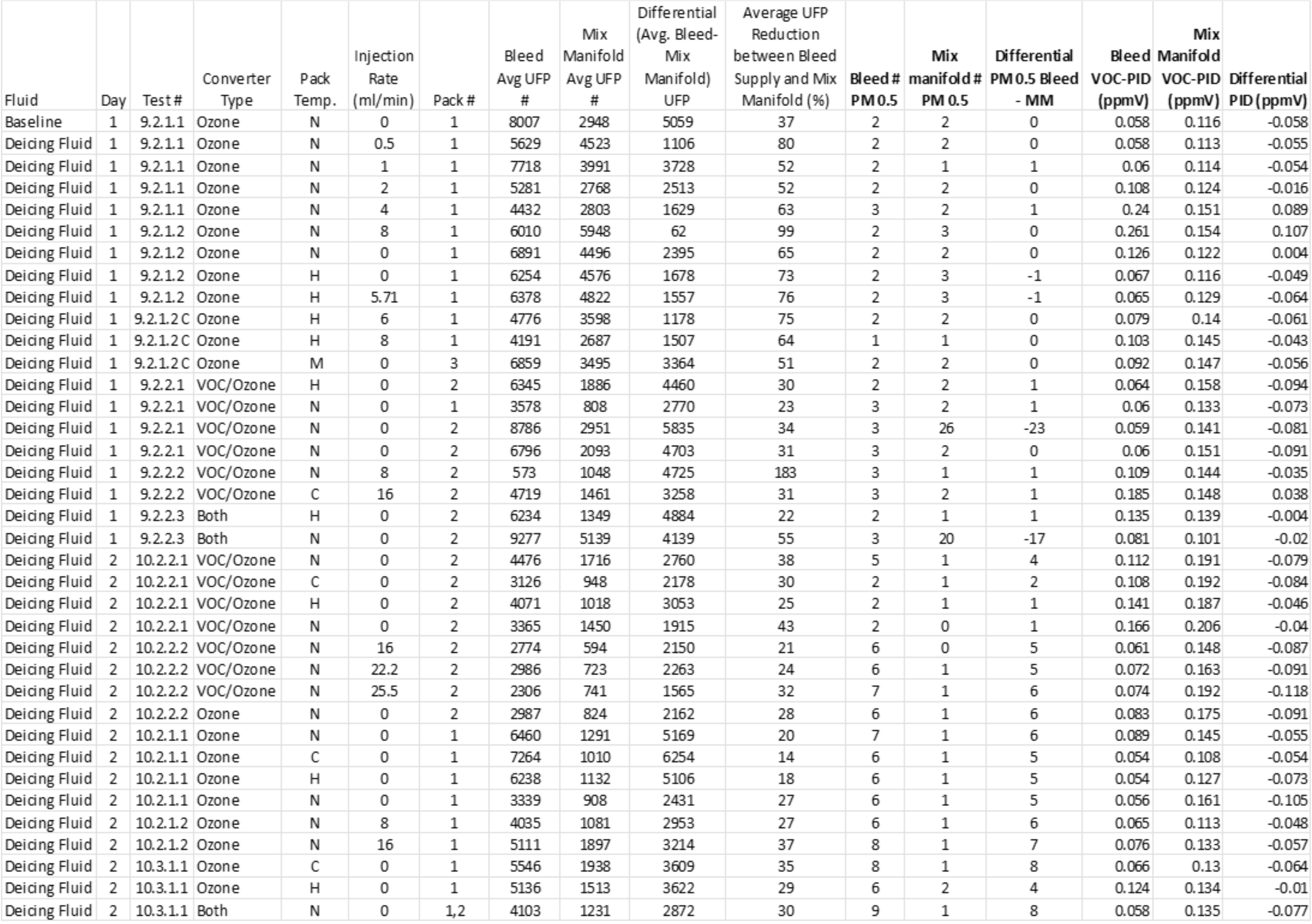
The UFP removal percentage between the ozone and VOC/ozone converter, and the mix manifold was plotted for samples in deicing fluid ingestion portion of the test is presented in Figure 127 and for oil injection in Figure 128. The percentage of UFP measured in the mix manifold ranged from a decrease 0 to 180 percent compared to the quantity of UFP entering the ECS system when ingesting deicing fluid. The majority of data indicates that there is a reduction between 40 percent to 80 percent of UFP over the ingestion range of 0 to 26 ml/minute deicing fluid.

Eighty percent up to an increase of 280 percent of the quantity of UFP entering the ECS system when ingesting turbine oil. Most data indicates that there is a reduction between 40 percent to 80 percent of UFP over the ingestion range of 0 to 6 ml/minute turbine oil.

The test data for UFP are graphically depicted for the deicing fluid tests in Figure 129 and Figure 130. The test data for UFP are graphically depicted for the turbine oil fluid tests in Figure 131 and Figure 132.

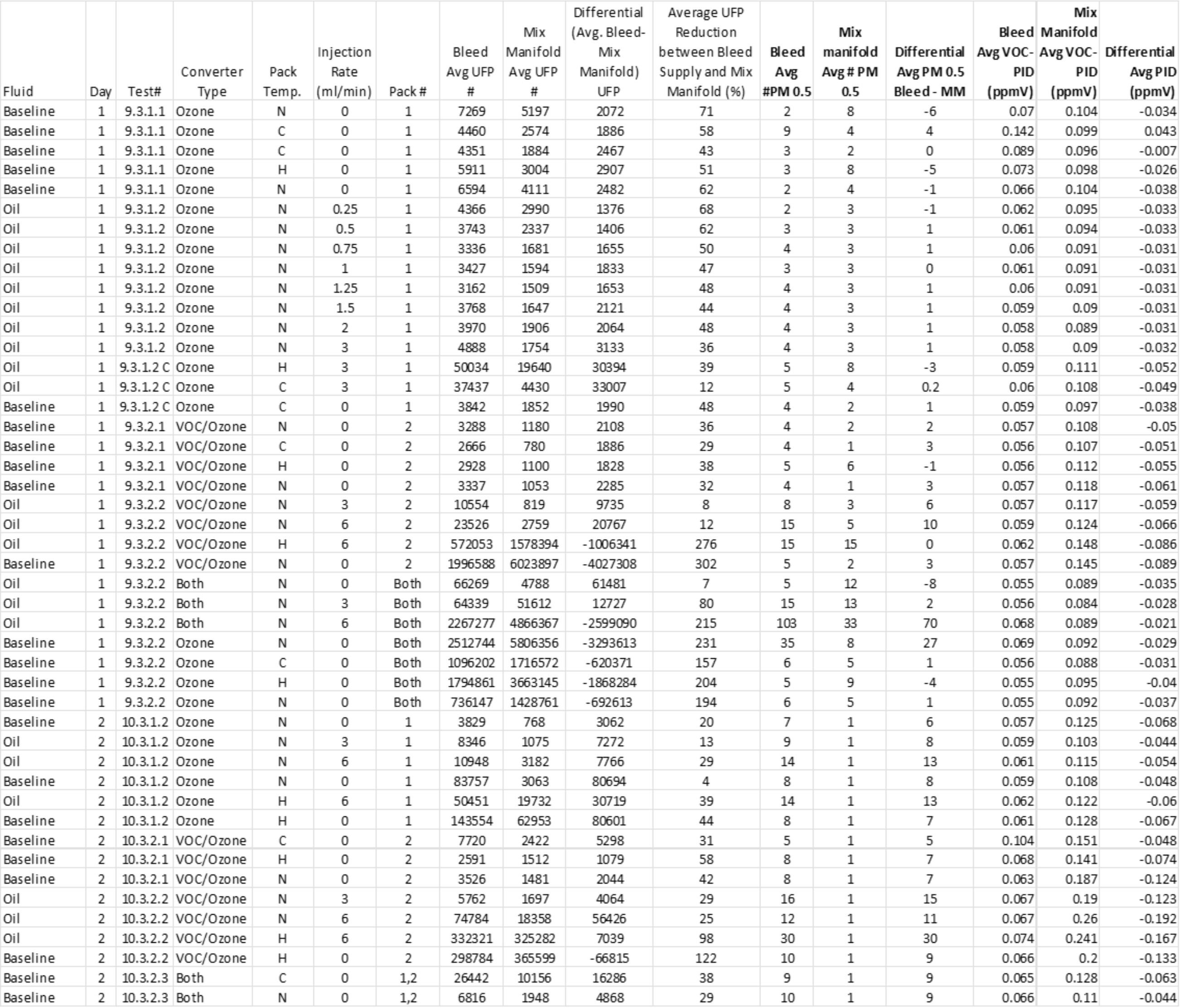
Conclusions from Figure 127 and Figure 128, which summarize the data in Figure 125 and Figure 126 are as follows:

- Total UFP numbers during the deicing fluid ingestion portion of the testing did not exceed 10,000 particles per cubic centimeter.
- Total UFP numbers during the turbine oil ingestion portion ranged over 1 x 107 particles per cubic centimeter.
- The number of UFP measured in the mix manifold during the deicing fluid portion of the test was always less than the number of UFP measured at the ozone converter inlet.
- The number of UFP measured in the mix manifold during the turbine oil ingestion testing ranged from 100 percent fewer UFP per cubic centimeter, to almost 280 percent more UFP per cubic centimeter.
- Data was not collected at the ozone converter outlet, so it is not possible to determine if the increase in particle number during the oil ingestion testing was related to particle formation between the ozone or VOC/ozone converters and the pack, or if the effect on particle increase or reduction was related to interactions within the air conditioning packs.



Fluid	Day	Test #	Converter Type	Pack Temp.	Injection Rate (ml/min)	Pack #	Bleed Avg UFP #	Mix Manifold Avg UFP #	Differential (Avg. Bleed-Mix Manifold) UFP	Average UFP Reduction between Bleed Supply and Mix Manifold (%)	**Bleed # PM 0.5**	**Mix manifold # PM 0.5**	**Differential PM 0.5 Bleed - MM**	**Bleed VOC-PID (ppmV)**	**Mix Manifold VOC-PID (ppmV)**	**Differential PID (ppmV)**
Baseline	1	9.2.1.1	Ozone	N	0	1	8007	2948	5059	37	2	2	0	0.058	0.116	-0.058
Deicing Fluid	1	9.2.1.1	Ozone	N	0.5	1	5629	4523	1106	80	2	2	0	0.058	0.113	-0.055
Deicing Fluid	1	9.2.1.1	Ozone	N	1	1	7718	3991	3728	52	2	1	1	0.06	0.114	-0.054
Deicing Fluid	1	9.2.1.1	Ozone	N	2	1	5281	2768	2513	52	2	2	0	0.108	0.124	-0.016
Deicing Fluid	1	9.2.1.1	Ozone	N	4	1	4432	2803	1629	63	3	2	1	0.24	0.151	0.089
Deicing Fluid	1	9.2.1.2	Ozone	N	8	1	6010	5948	62	99	2	3	0	0.261	0.154	0.107
Deicing Fluid	1	9.2.1.2	Ozone	N	0	1	6891	4496	2395	65	2	2	0	0.126	0.122	0.004
Deicing Fluid	1	9.2.1.2	Ozone	H	0	1	6254	4576	1678	73	2	3	-1	0.067	0.116	-0.049
Deicing Fluid	1	9.2.1.2	Ozone	H	5.71	1	6378	4822	1557	76	2	3	-1	0.065	0.129	-0.064
Deicing Fluid	1	9.2.1.2 C	Ozone	H	6	1	4776	3598	1178	75	2	2	0	0.079	0.14	-0.061
Deicing Fluid	1	9.2.1.2 C	Ozone	H	8	1	4191	2687	1507	64	1	1	0	0.103	0.145	-0.043
Deicing Fluid	1	9.2.1.2 C	Ozone	M	0	3	6859	3495	3364	51	2	2	0	0.092	0.147	-0.056
Deicing Fluid	1	9.2.2.1	VOC/Ozone	H	0	2	6345	1886	4460	30	2	2	1	0.064	0.158	-0.094
Deicing Fluid	1	9.2.2.1	VOC/Ozone	N	0	1	3578	808	2770	23	3	2	1	0.06	0.133	-0.073
Deicing Fluid	1	9.2.2.1	VOC/Ozone	N	0	2	8786	2951	5835	34	3	26	-23	0.059	0.141	-0.081
Deicing Fluid	1	9.2.2.1	VOC/Ozone	N	0	2	6796	2093	4703	31	3	2	0	0.06	0.151	-0.091
Deicing Fluid	1	9.2.2.2	VOC/Ozone	N	8	2	573	1048	4725	183	3	1	1	0.109	0.144	-0.035
Deicing Fluid	1	9.2.2.2	VOC/Ozone	C	16	2	4719	1461	3258	31	3	2	1	0.185	0.148	0.038
Deicing Fluid	1	9.2.2.3	Both	H	0	2	6234	1349	4884	22	2	1	1	0.135	0.139	-0.004
Deicing Fluid	1	9.2.2.3	Both	N	0	2	9277	5139	4139	55	3	20	-17	0.081	0.101	-0.02
Deicing Fluid	2	10.2.2.1	VOC/Ozone	N	0	2	4476	1716	2760	38	5	1	4	0.112	0.191	-0.079
Deicing Fluid	2	10.2.2.1	VOC/Ozone	C	0	2	3126	948	2178	30	2	1	2	0.108	0.192	-0.084
Deicing Fluid	2	10.2.2.1	VOC/Ozone	H	0	2	4071	1018	3053	25	2	1	1	0.141	0.187	-0.046
Deicing Fluid	2	10.2.2.1	VOC/Ozone	N	0	2	3365	1450	1915	43	2	0	1	0.166	0.206	-0.04
Deicing Fluid	2	10.2.2.2	VOC/Ozone	N	16	2	2774	594	2150	21	6	0	5	0.061	0.148	-0.087
Deicing Fluid	2	10.2.2.2	VOC/Ozone	N	22.2	2	2986	723	2263	24	6	1	5	0.072	0.163	-0.091
Deicing Fluid	2	10.2.2.2	VOC/Ozone	N	25.5	2	2306	741	1565	32	7	1	6	0.074	0.192	-0.118
Deicing Fluid	2	10.2.2.2	Ozone	N	0	2	2987	824	2162	28	6	1	6	0.083	0.175	-0.091
Deicing Fluid	2	10.2.1.1	Ozone	N	0	1	6460	1291	5169	20	7	1	6	0.089	0.145	-0.055
Deicing Fluid	2	10.2.1.1	Ozone	C	0	1	7264	1010	6254	14	6	1	5	0.054	0.108	-0.054
Deicing Fluid	2	10.2.1.1	Ozone	H	0	1	6238	1132	5106	18	6	1	5	0.054	0.127	-0.073
Deicing Fluid	2	10.2.1.1	Ozone	N	0	1	3339	908	2431	27	6	1	5	0.056	0.161	-0.105
Deicing Fluid	2	10.2.1.2	Ozone	N	8	1	4035	1081	2953	27	6	1	6	0.065	0.113	-0.048
Deicing Fluid	2	10.2.1.2	Ozone	N	16	1	5111	1897	3214	37	8	1	7	0.076	0.133	-0.057
Deicing Fluid	2	10.3.1.1	Ozone	C	0	1	5546	1938	3609	35	8	1	8	0.066	0.13	-0.064
Deicing Fluid	2	10.3.1.1	Ozone	H	0	1	5136	1513	3622	29	6	2	4	0.124	0.134	-0.01
Deicing Fluid	2	10.3.1.1	Both	N	0	1,2	4103	1231	2872	30	9	1	8	0.058	0.135	-0.077

Figure 125. UFP, PM, and VOC data for deicing fluid injection



Fluid	Day	Test#	Converter Type	Pack Temp.	Injection Rate (ml/min)	Pack #	Bleed Avg UFP #	Mix Manifold Avg UFP #	Differential (Avg. Bleed-Mix Manifold) UFP	Average UFP Reduction between Bleed Supply and Mix Manifold (%)	**Bleed Avg #PM 0.5**	**Mix manifold Avg # PM 0.5**	**Differential Avg PM 0.5 Bleed - MM**	**Bleed Avg VOC-PID (ppmV)**	**Mix Manifold Avg VOC-PID (ppmV)**	**Differential Avg PID (ppmV)**
Baseline	1	9.3.1.1	Ozone	N	0	1	7269	5197	2072	71	2	8	-6	0.07	0.104	-0.034
Baseline	1	9.3.1.1	Ozone	C	0	1	4460	2574	1886	58	9	4	4	0.142	0.099	0.043
Baseline	1	9.3.1.1	Ozone	C	0	1	4351	1884	2467	43	3	2	0	0.089	0.096	-0.007
Baseline	1	9.3.1.1	Ozone	H	0	1	5911	3004	2907	51	3	8	-5	0.073	0.098	-0.026
Baseline	1	9.3.1.1	Ozone	N	0	1	6594	4111	2482	62	2	4	-1	0.066	0.104	-0.038
Oil	1	9.3.1.2	Ozone	N	0.25	1	4366	2990	1376	68	2	3	-1	0.062	0.095	-0.033
Oil	1	9.3.1.2	Ozone	N	0.5	1	3743	2337	1406	62	3	3	1	0.061	0.094	-0.033
Oil	1	9.3.1.2	Ozone	N	0.75	1	3336	1681	1655	50	4	3	1	0.06	0.091	-0.031
Oil	1	9.3.1.2	Ozone	N	1	1	3427	1594	1833	47	3	3	0	0.061	0.091	-0.031
Oil	1	9.3.1.2	Ozone	N	1.25	1	3162	1509	1653	48	4	3	1	0.06	0.091	-0.031
Oil	1	9.3.1.2	Ozone	N	1.5	1	3768	1647	2121	44	4	3	1	0.059	0.09	-0.031
Oil	1	9.3.1.2	Ozone	N	2	1	3970	1906	2064	48	4	3	1	0.058	0.089	-0.031
Oil	1	9.3.1.2	Ozone	N	3	1	4888	1754	3133	36	4	3	1	0.058	0.09	-0.032
Oil	1	9.3.1.2 C	Ozone	H	3	1	50034	19640	30394	39	5	8	-3	0.059	0.111	-0.052
Oil	1	9.3.1.2 C	Ozone	C	3	1	37437	4430	33007	12	5	4	0.2	0.06	0.108	-0.049
Baseline	1	9.3.1.2 C	Ozone	C	0	1	3842	1852	1990	48	4	2	1	0.059	0.097	-0.038
Baseline	1	9.3.2.1	VOC/Ozone	N	0	2	3288	1180	2108	36	4	2	2	0.057	0.108	-0.05
Baseline	1	9.3.2.1	VOC/Ozone	C	0	2	2666	780	1886	29	4	1	3	0.056	0.107	-0.051
Baseline	1	9.3.2.1	VOC/Ozone	H	0	2	2928	1100	1828	38	5	6	-1	0.056	0.112	-0.055
Baseline	1	9.3.2.1	VOC/Ozone	N	0	2	3337	1053	2285	32	4	1	3	0.057	0.118	-0.061
Oil	1	9.3.2.2	VOC/Ozone	N	3	2	10554	819	9735	8	8	3	6	0.057	0.117	-0.059
Oil	1	9.3.2.2	VOC/Ozone	N	6	2	23526	2759	20767	12	15	5	10	0.059	0.124	-0.066
Oil	1	9.3.2.2	VOC/Ozone	H	6	2	572053	1578394	-1006341	276	15	15	0	0.062	0.148	-0.086
Baseline	1	9.3.2.2	VOC/Ozone	N	0	2	1996588	6023897	-4027308	302	5	2	3	0.057	0.145	-0.089
Oil	1	9.3.2.2	Both	N	0	Both	66269	4788	61481	7	5	12	-8	0.055	0.089	-0.035
Oil	1	9.3.2.2	Both	N	3	Both	64339	51612	12727	80	15	13	2	0.056	0.084	-0.028
Oil	1	9.3.2.2	Both	N	6	Both	2267277	4866367	-2599090	215	103	33	70	0.068	0.089	-0.021
Baseline	1	9.3.2.2	Ozone	N	0	Both	2512744	5806356	-3293613	231	35	8	27	0.069	0.092	-0.029
Baseline	1	9.3.2.2	Ozone	C	0	Both	1096202	1716572	-620371	157	6	5	1	0.056	0.088	-0.031
Baseline	1	9.3.2.2	Ozone	H	0	Both	1794861	3663145	-1868284	204	5	9	-4	0.055	0.095	-0.04
Baseline	1	9.3.2.2	Ozone	N	0	Both	736147	1428761	-692613	194	6	5	1	0.055	0.092	-0.037
Baseline	2	10.3.1.2	Ozone	N	0	1	3829	768	3062	20	7	1	6	0.057	0.125	-0.068
Oil	2	10.3.1.2	Ozone	N	3	1	8346	1075	7272	13	9	1	8	0.059	0.103	-0.044
Oil	2	10.3.1.2	Ozone	N	6	1	10948	3182	7766	29	14	1	13	0.061	0.115	-0.054
Baseline	2	10.3.1.2	Ozone	N	0	1	83757	3063	80694	4	8	1	8	0.059	0.108	-0.048
Oil	2	10.3.1.2	Ozone	H	6	1	50451	19732	30719	39	14	1	13	0.062	0.122	-0.06
Baseline	2	10.3.1.2	Ozone	H	0	1	143554	62953	80601	44	8	1	7	0.061	0.128	-0.067
Baseline	2	10.3.2.1	VOC/Ozone	C	0	2	7720	2422	5298	31	5	1	5	0.104	0.151	-0.048
Baseline	2	10.3.2.1	VOC/Ozone	H	0	2	2591	1512	1079	58	8	1	7	0.068	0.141	-0.074
Baseline	2	10.3.2.1	VOC/Ozone	N	0	2	3526	1481	2044	42	8	1	7	0.063	0.187	-0.124
Oil	2	10.3.2.2	VOC/Ozone	N	3	2	5762	1697	4064	29	16	1	15	0.067	0.19	-0.123
Oil	2	10.3.2.2	VOC/Ozone	N	6	2	74784	18358	56426	25	12	1	11	0.067	0.26	-0.192
Oil	2	10.3.2.2	VOC/Ozone	H	6	2	332321	325282	7039	98	30	1	30	0.074	0.241	-0.167
Baseline	2	10.3.2.2	VOC/Ozone	H	0	2	298784	365599	-66815	122	10	1	9	0.066	0.2	-0.133
Baseline	2	10.3.2.3	Both	C	0	1,2	26442	10156	16286	38	9	1	9	0.065	0.128	-0.063
Baseline	2	10.3.2.3	Both	N	0	1,2	6816	1948	4868	29	10	1	9	0.066	0.11	-0.044

Figure 126. UFP, PM, and VOC data for turbine oil injection

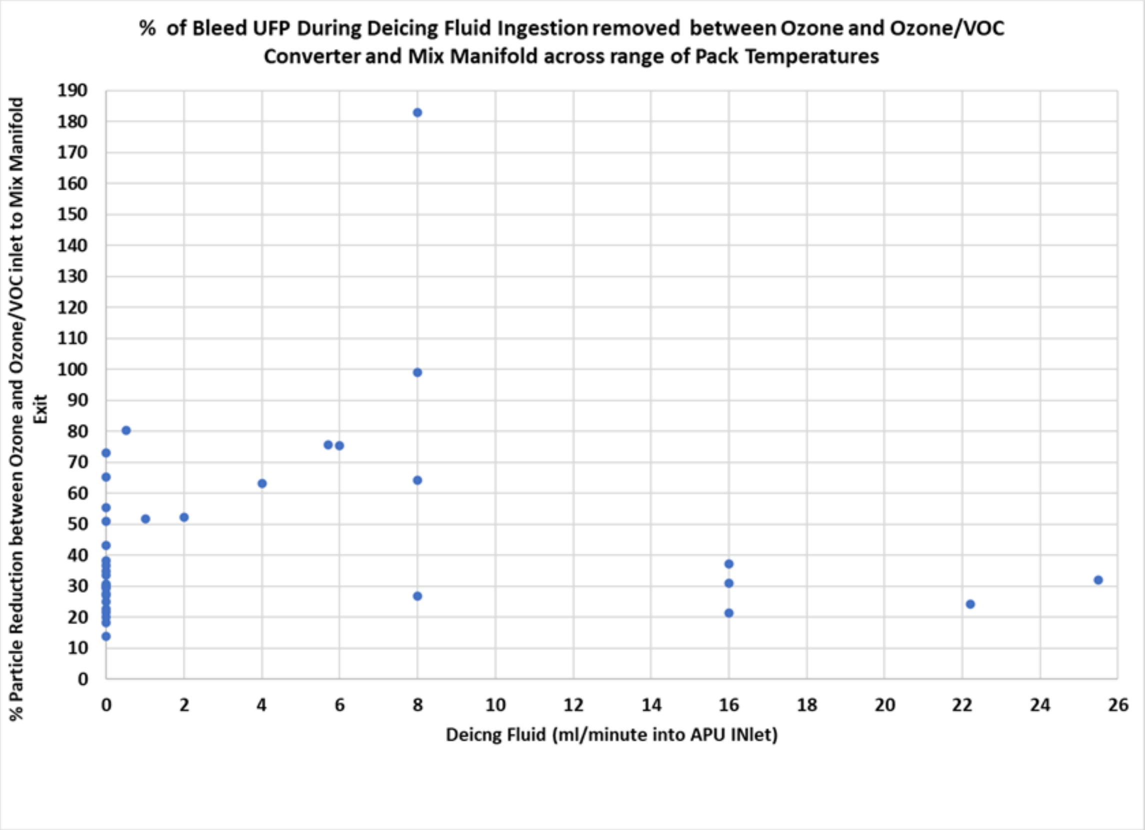


Figure 127. Percentage of UFP removed by ECS during deicing fluid ingestion testing

The UFP change between the ozone and the VOC/ozone converter, and the mix manifold was plotted for samples in the turbine oil ingestion portion of the test is presented in Figure 128.

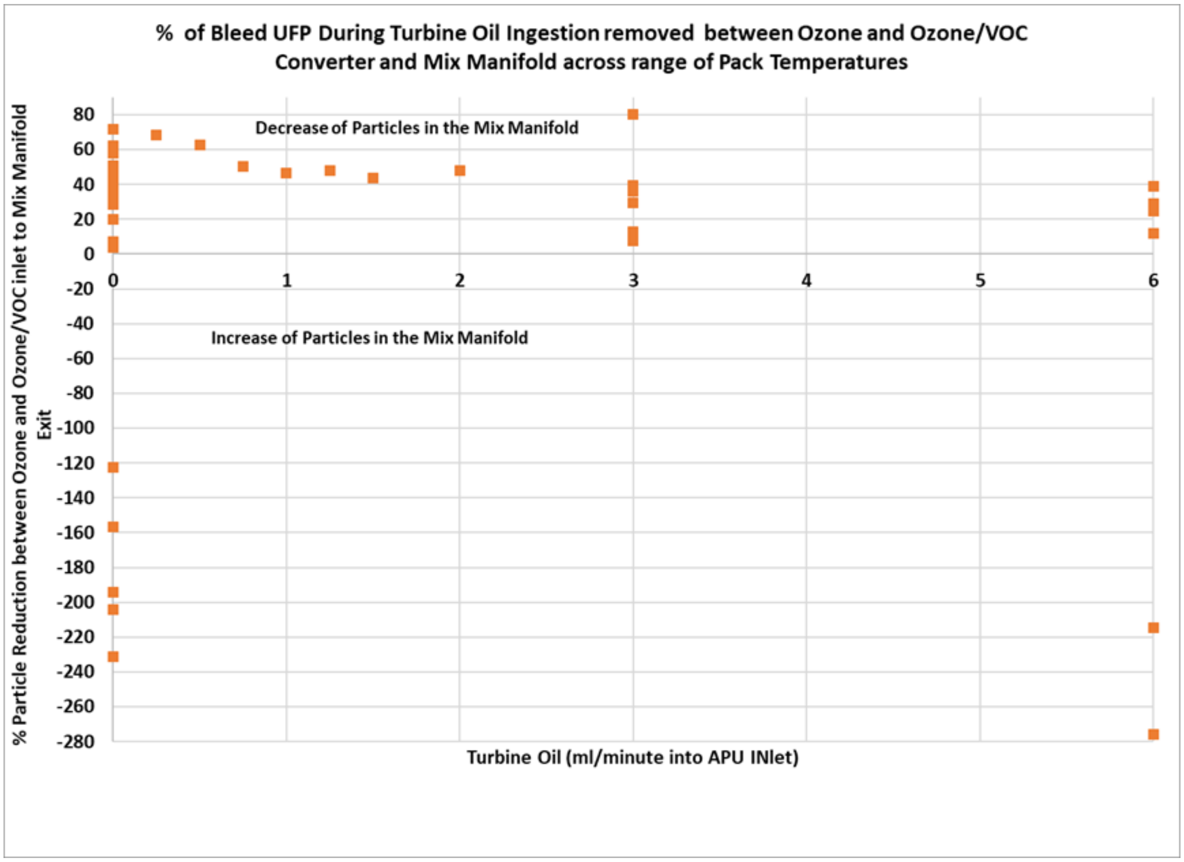


Figure 128. Percentage of UFP removed by ECS during turbine oil ingestion testing

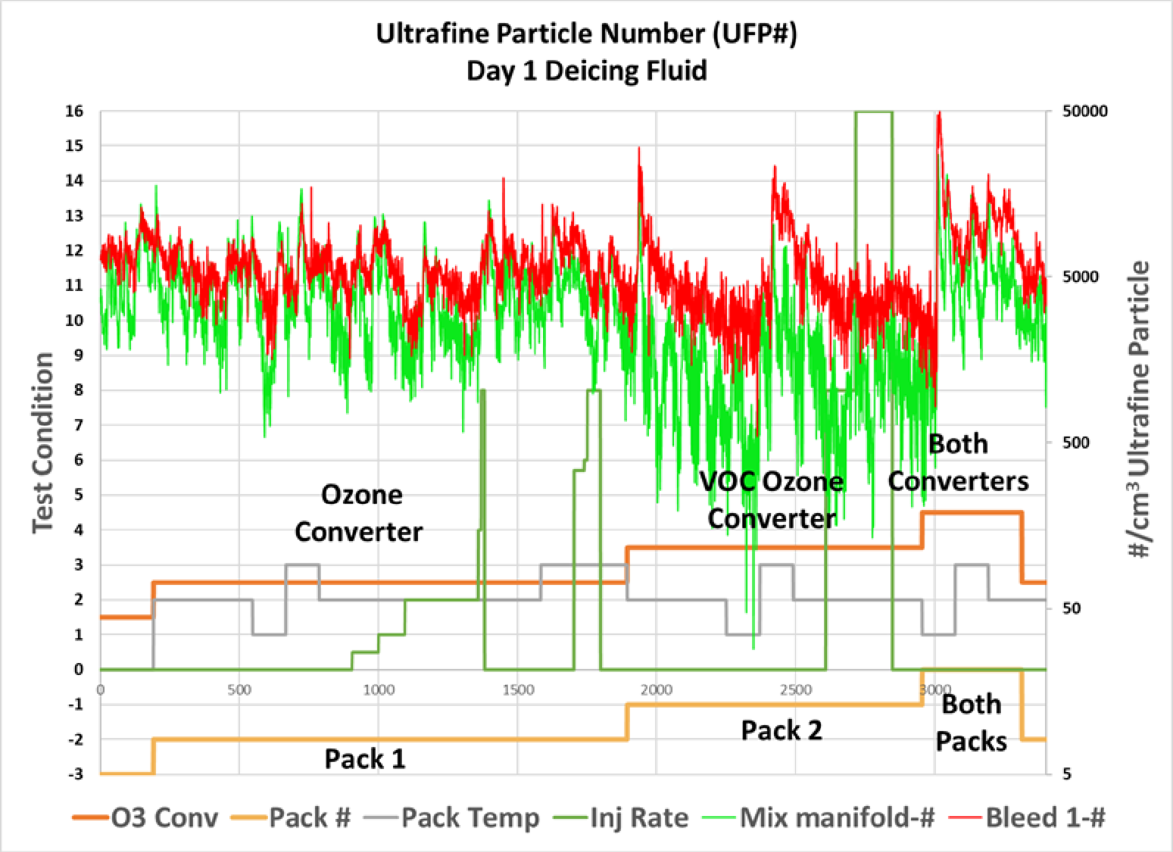


Figure 129. UFP number response to deicing fluid (Corona Discharge) day 1

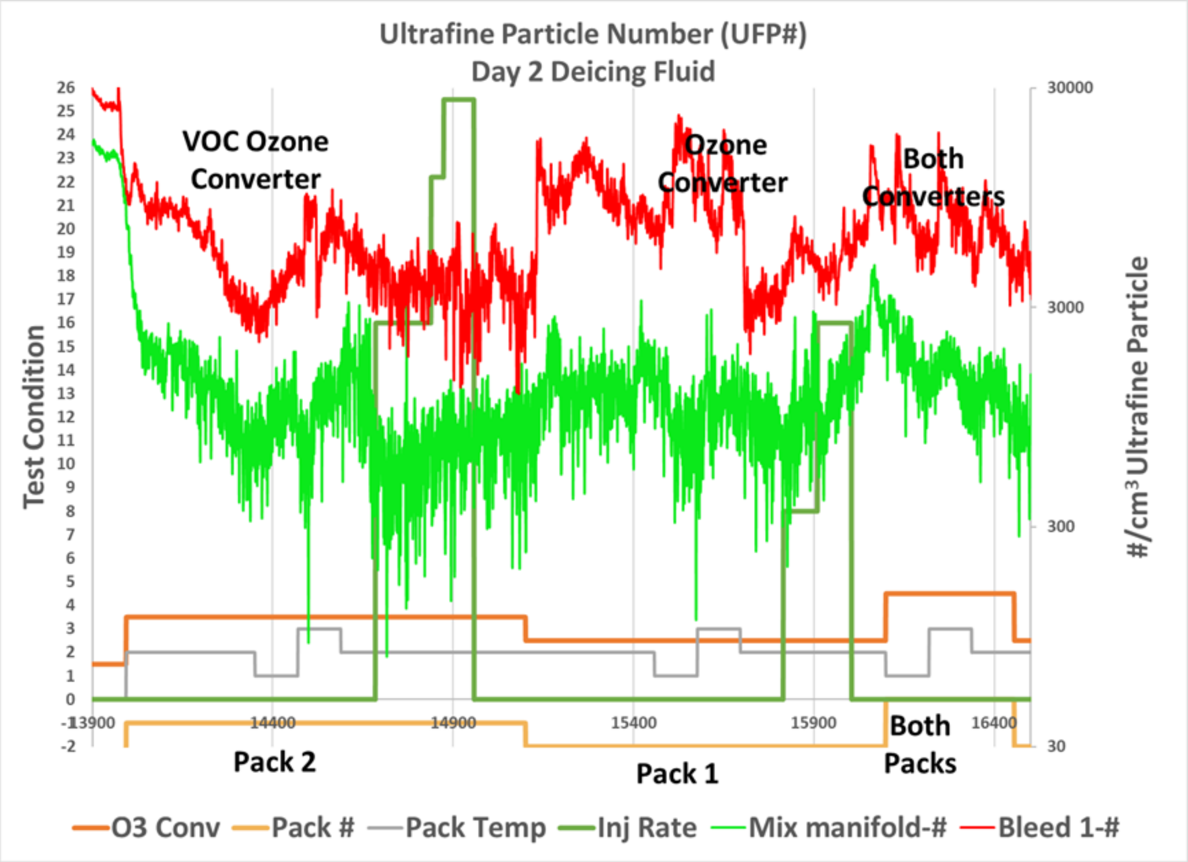


Figure 130. UFP number response to deicing fluid (Corona Wire) day 2

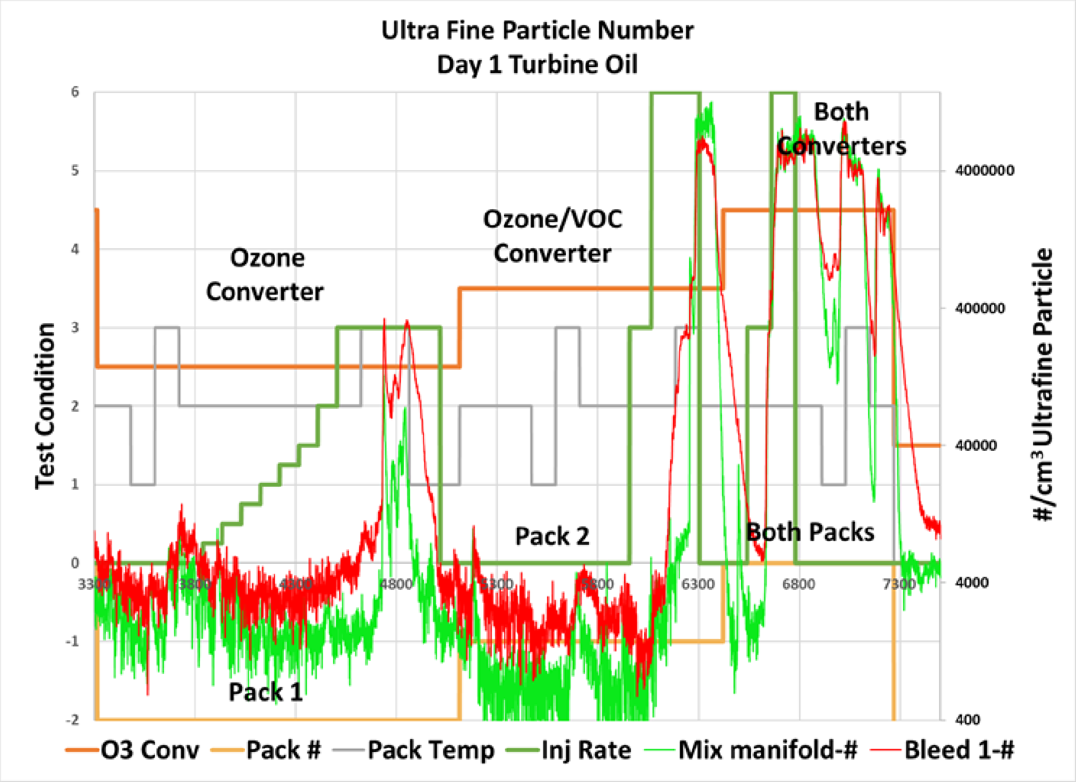


Figure 131. UFP number response - turbine oil (Corona Wire) day 1

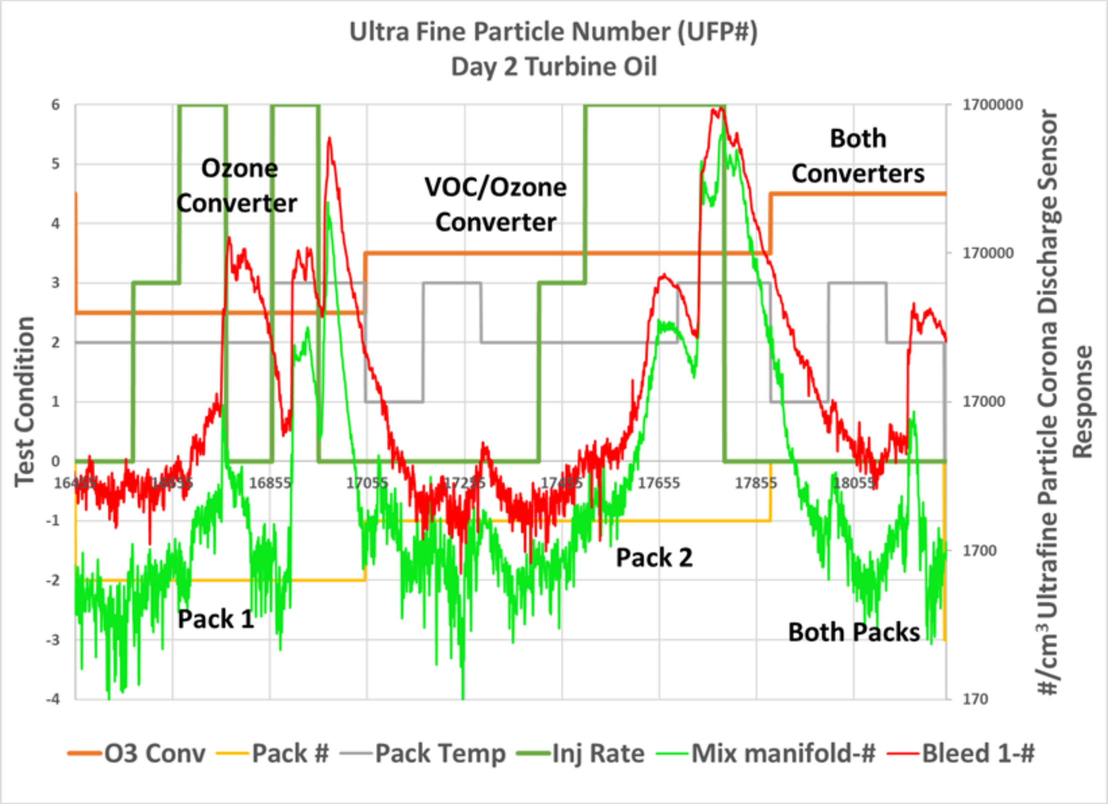


Figure 132. UFP number response to turbine oil (Corona Discharge) day 2

4.5.2 PM 0.5 fine particles (red laser)

Fine particle (PM 0.5) number for deicing fluid ingestion are presented in Figure 133 and Figure 134.The findings from these charts are that levels of particles in the PM0.5 range were less than 100 particles per cubic centimeter during the deicing fluid ingestion test. Fine Particle (PM 0.5) numbers for turbine oil ingestion are presented in Figure 135 and Figure 136. Total PM 0.5 during the turbine oil ingestion test did not exceed 200 particles per cubic centimeter.

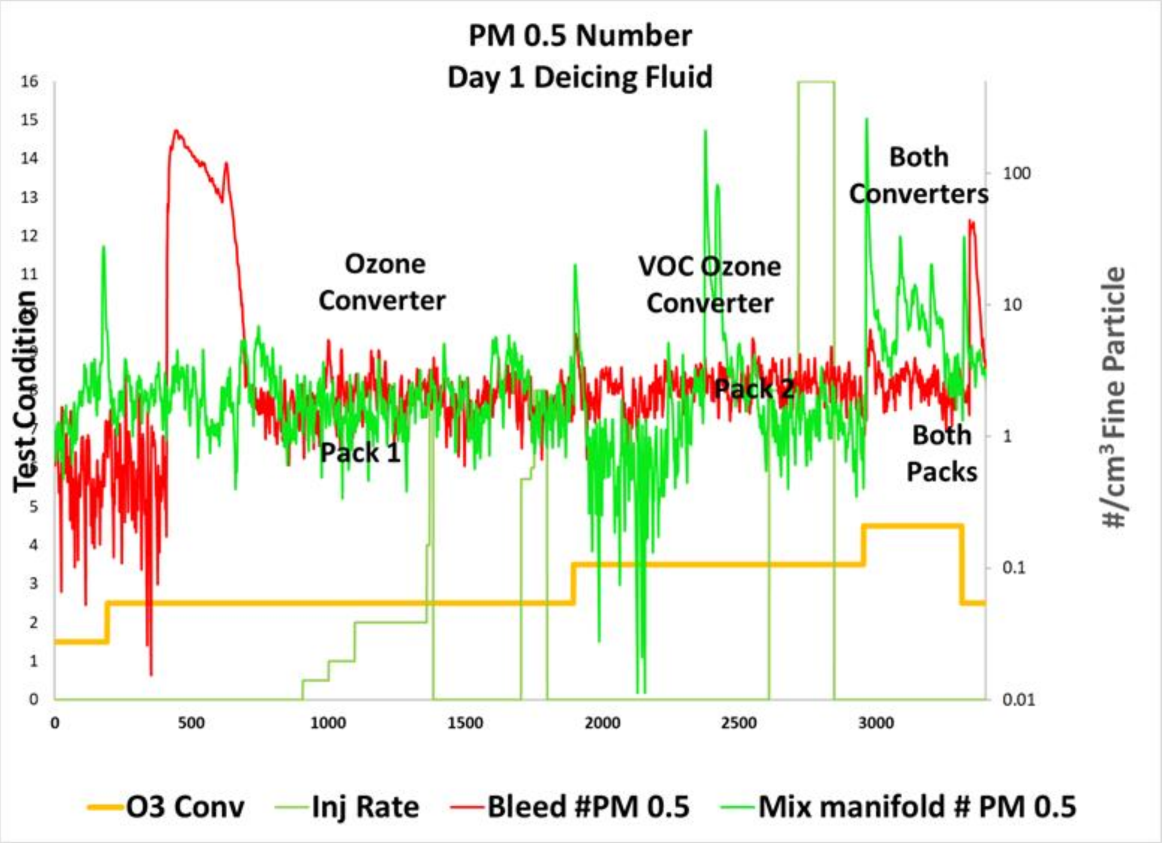


Figure 133. PM 0.5 sensor response to deicing fluid (red laser) day 1

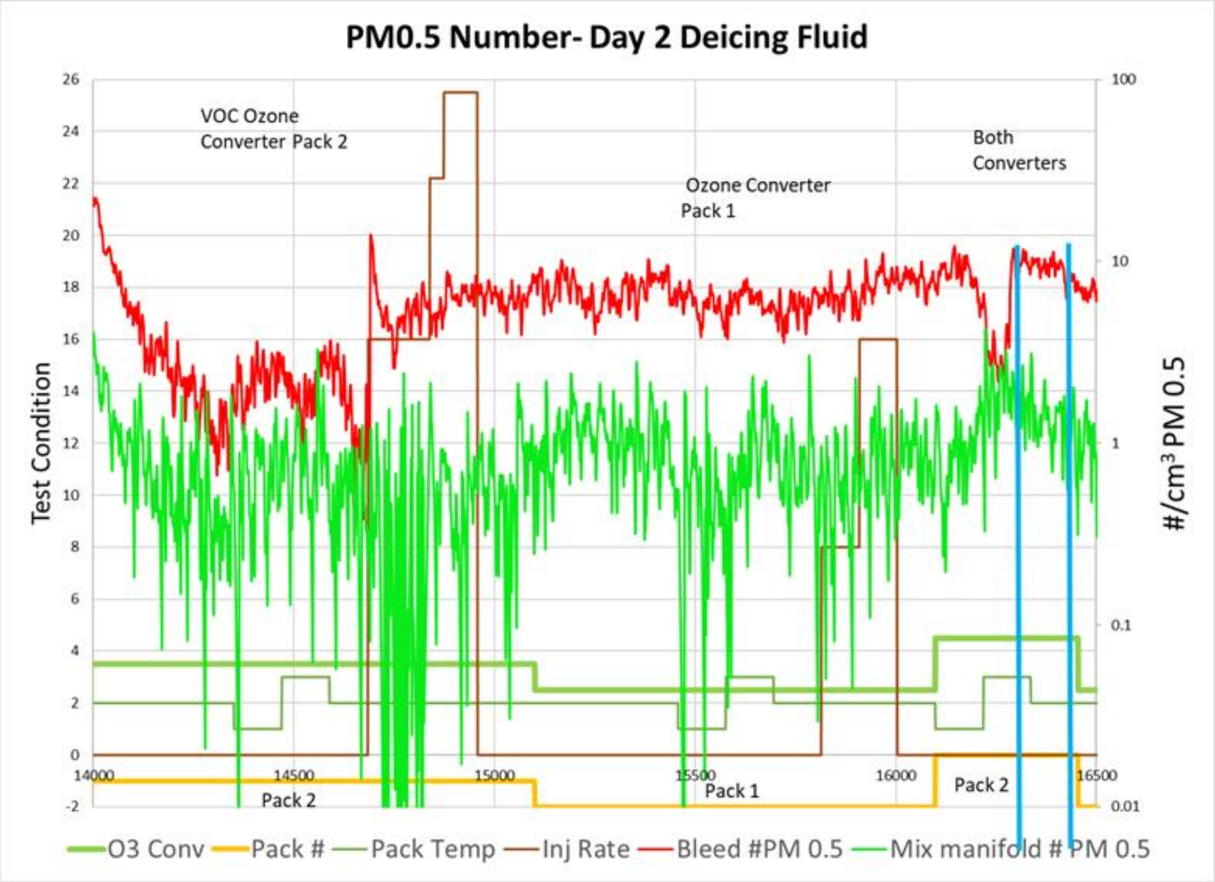


Figure 134. PM 0.5 sensor response to deicing fluid (red laser) day 2

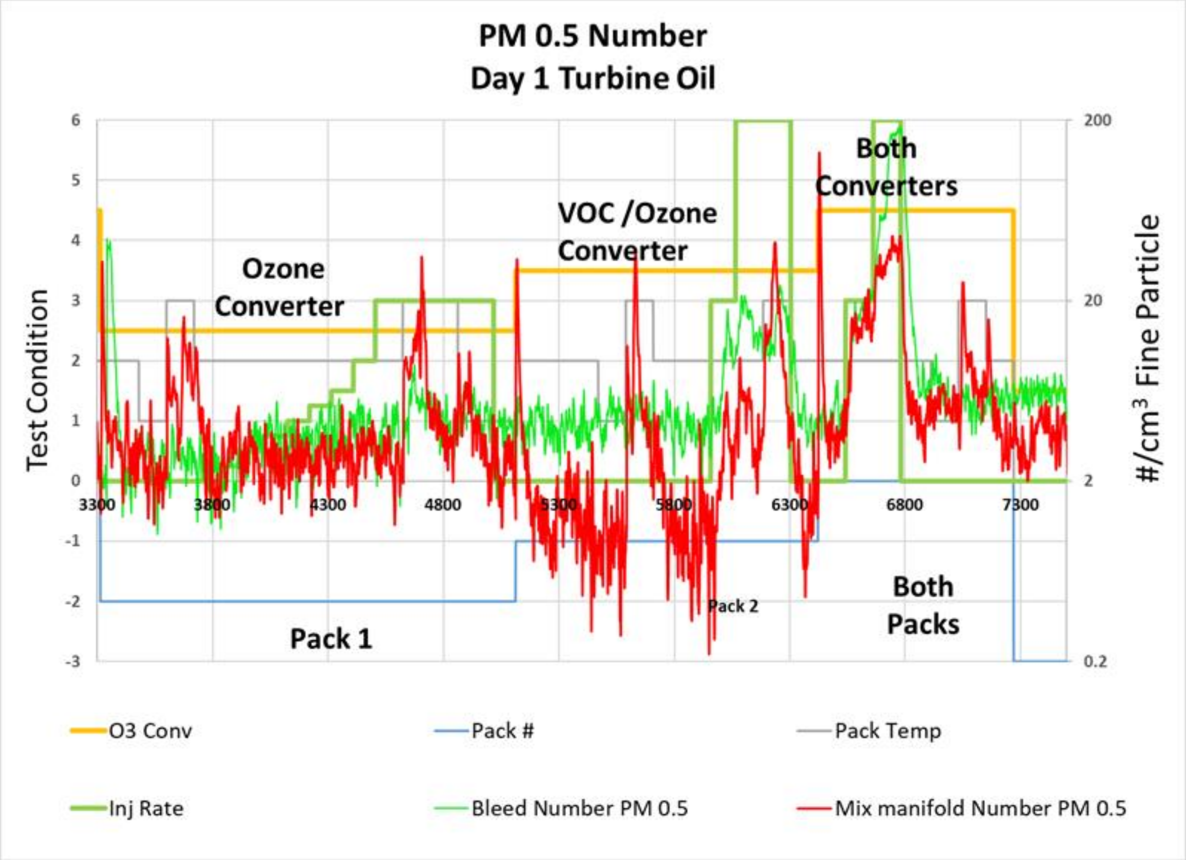


Figure 135. PM 0.5 sensor response to oil (red laser) day 1

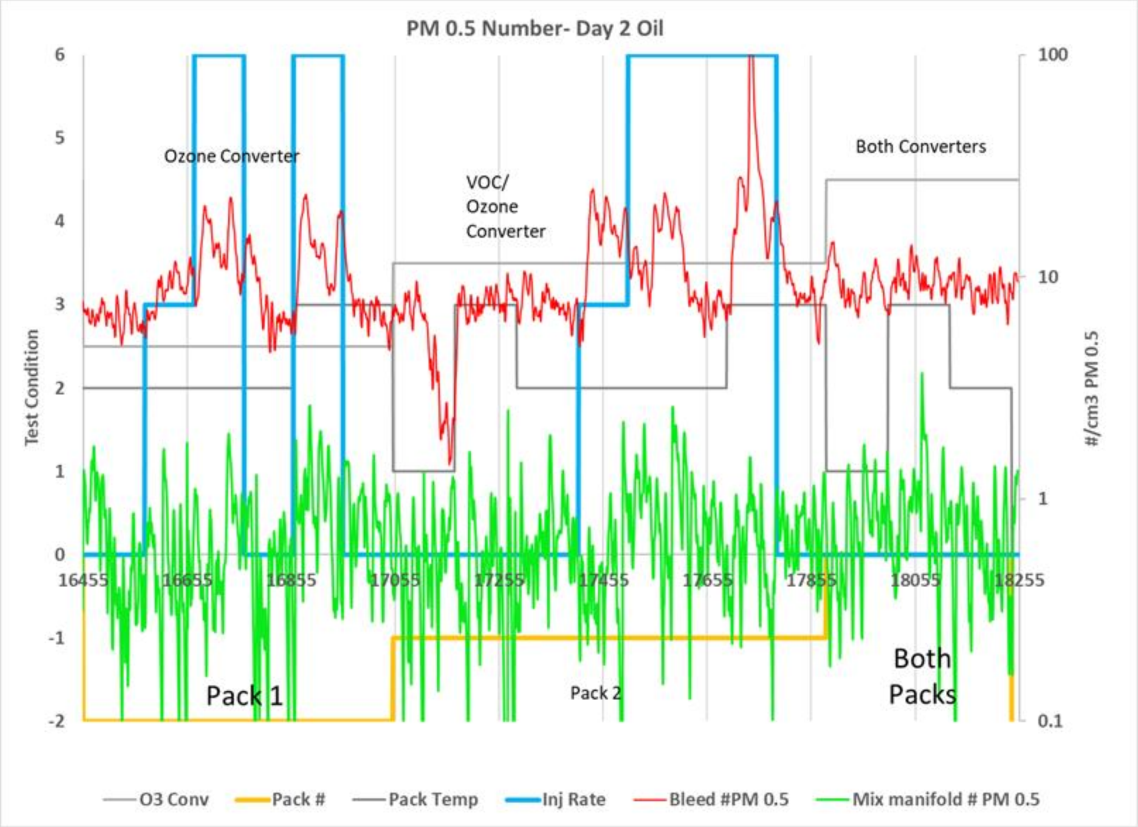


Figure 136. PM 0.5 sensor response to oil (red laser) day 2

4.5.3 Carbon monoxide (electrochemical sensor)

Carbon monoxide electrochemical sensor response for deicing fluid ingestion is presented in Figure 137 and Figure 138. Deicing fluid did not appear to generate a significant carbon monoxide electrochemical sensor response. There was a several tenths of a part per million increase observed when ingesting deicing fluid on the first day, but not on the second day. Carbon monoxide detection for turbine oil ingestion is presented in Figure 139 and Figure 140 . Similar responses were exhibited during turbine oil ingestion as were observed during deicing fluid ingestion. The electrochemical carbon monoxide sensors were operating near their minimum detection limit and the signal noise level was greater than 10 percent of the range of measurement. The total carbon monoxide level recorded was less than 0.3 ppm at the ozone converter inlet and the mix manifold exit. This supports the earlier findings of the study that carbon monoxide measurements utilizing electrochemical sensors would not be suitable for determining the presence of deicing fluid or turbine oil contamination in the bleed air.

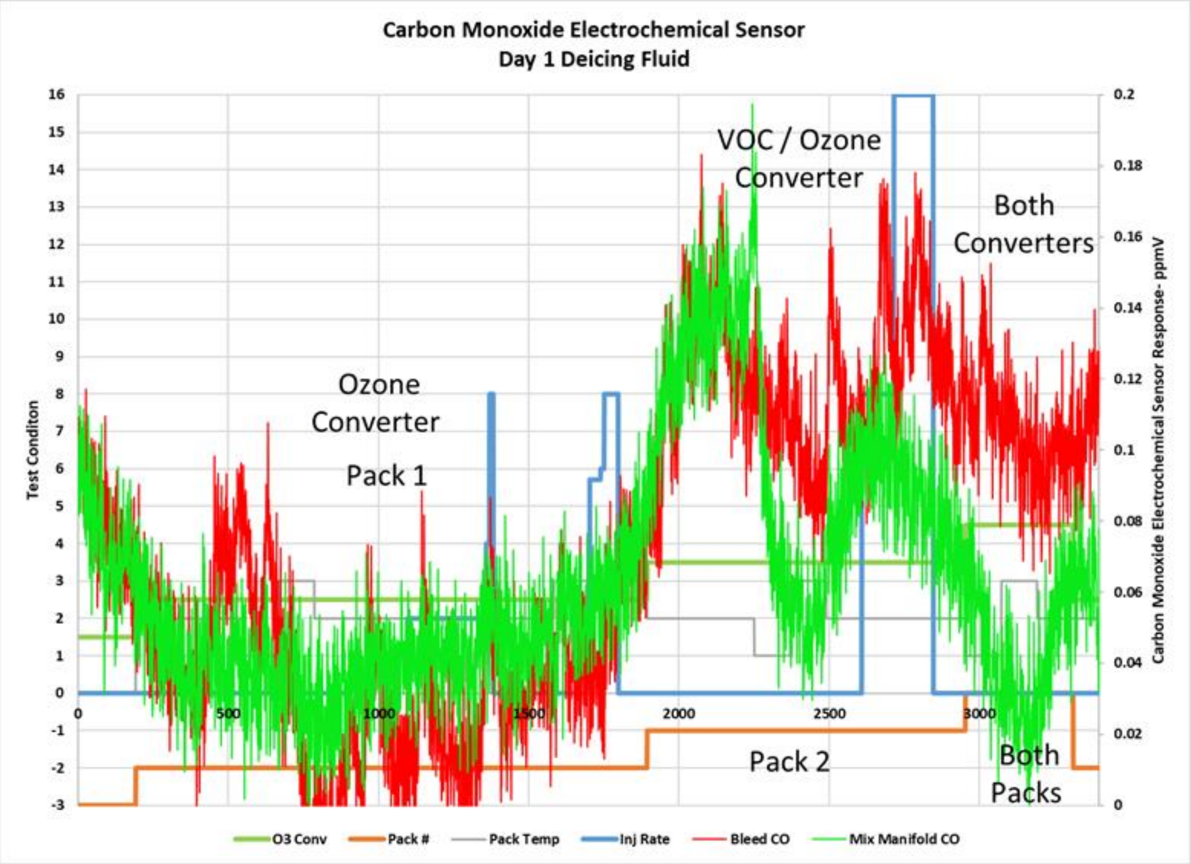


Figure 137. CO sensor response to deicing fluid (EC) day 1

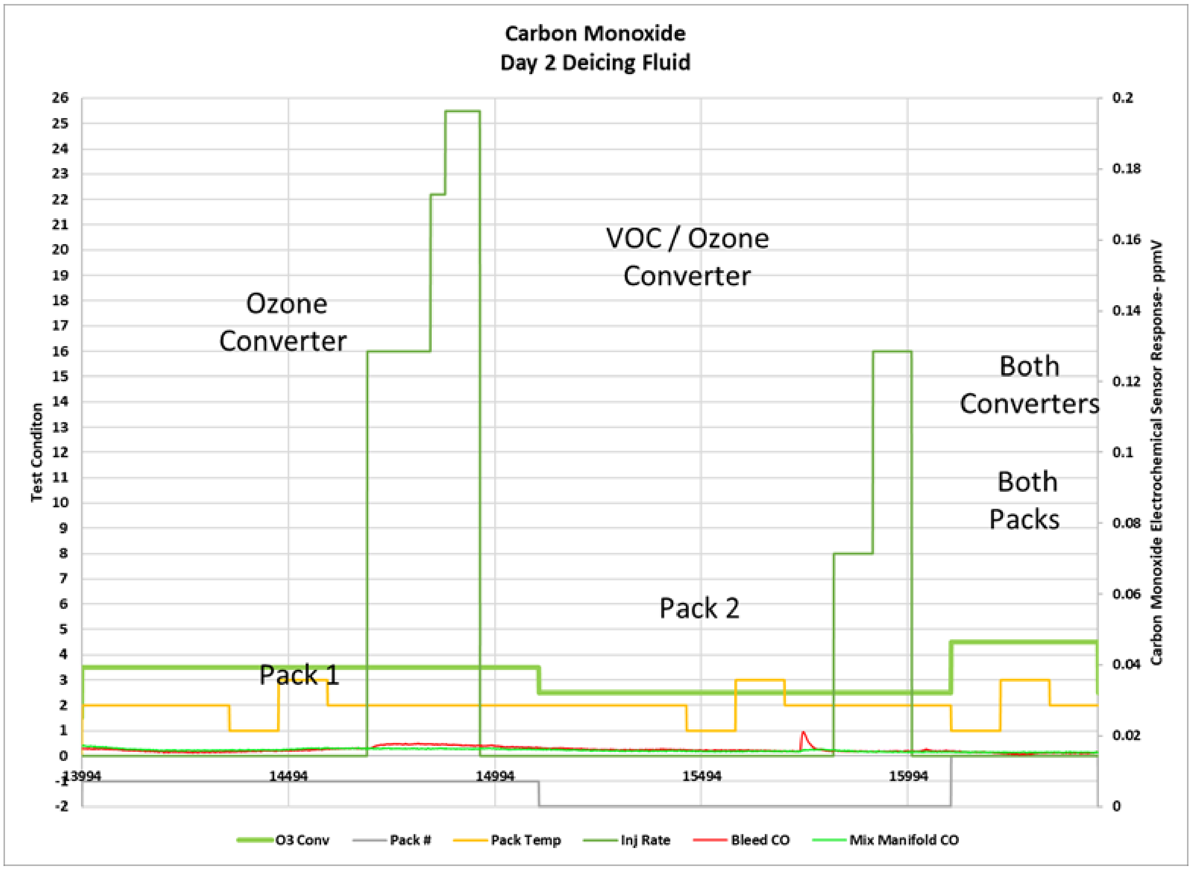


Figure 138. CO sensor response to deicing fluid (EC) day 2

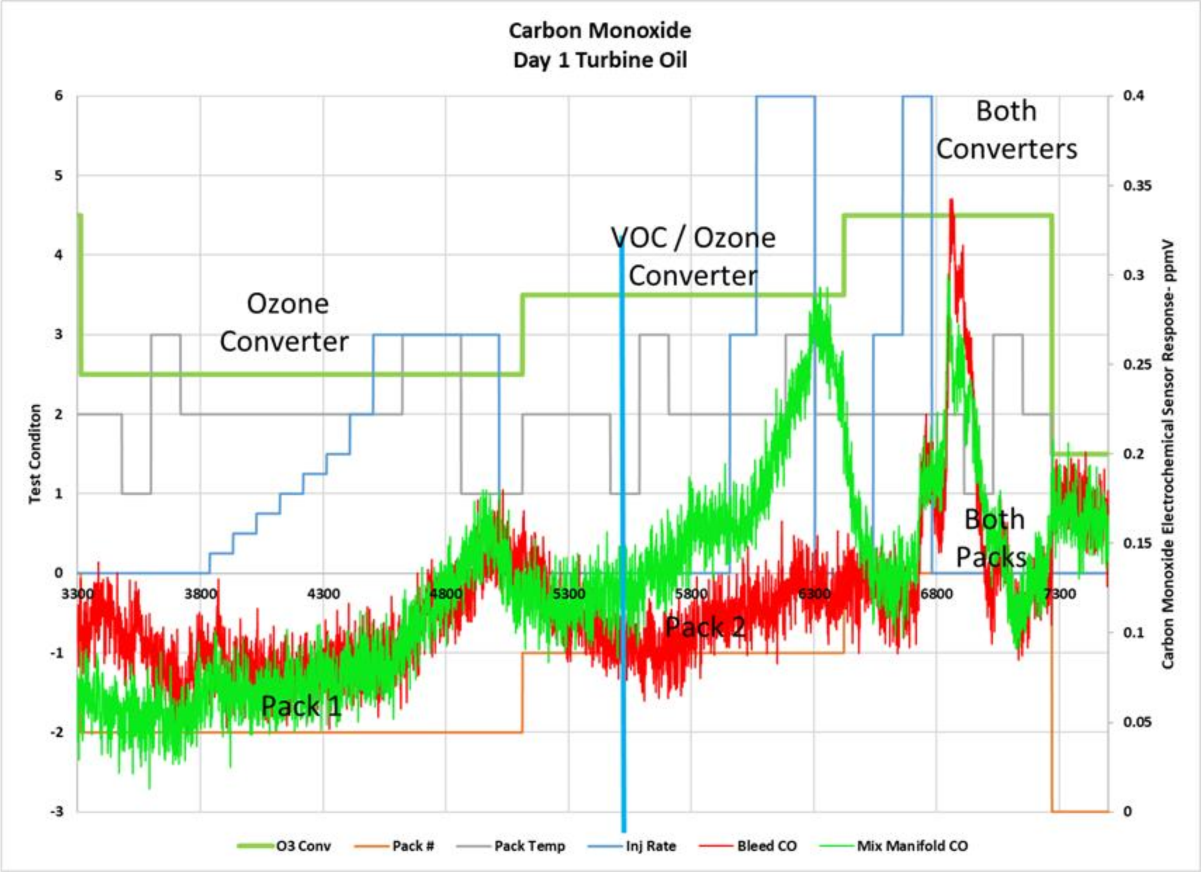


Figure 139. CO sensor response to oil (EC) day 1

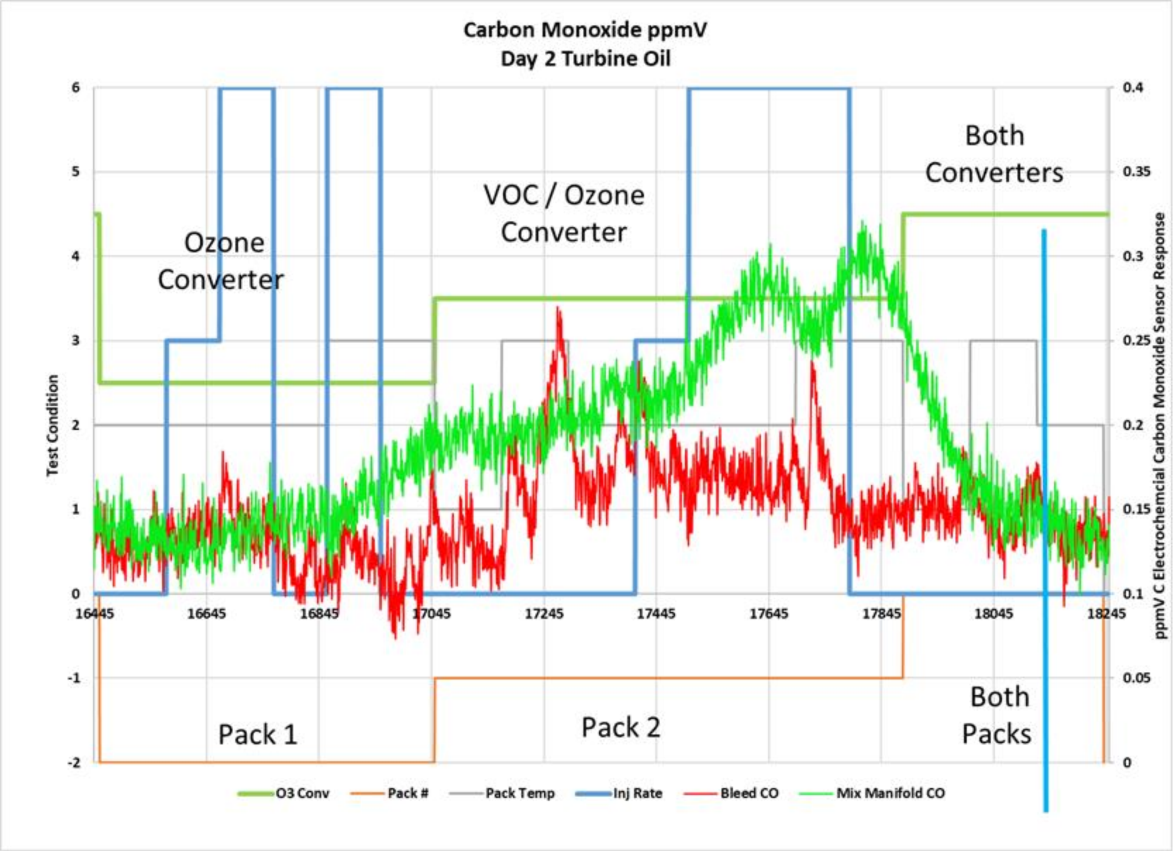


Figure 140. CO sensor response to turbine oil (EC) day 2

4.5.4 Carbon dioxide (non-dispersive infrared sensor)

Carbon dioxide sensor response for deicing fluid ingestion is presented in Figure 141 and Figure 142. The findings from these charts are as follows:

- Deicing fluid injection does not create a significant carbon dioxide sensor response.
- Increasing or decreasing pack temperature while injecting deicing fluid does not change sensor response.

Carbon dioxide sensor response to turbine oil ingestion is presented in Figure 143 and Figure 144. The findings from these charts are as follows:

- Turbine oil does not create a repeatable carbon dioxide sensor response during changes in ingestion rate of turbine oil.
- Increasing or decreasing pack temperature while injecting turbine oil does not affect carbon dioxide sensor response.

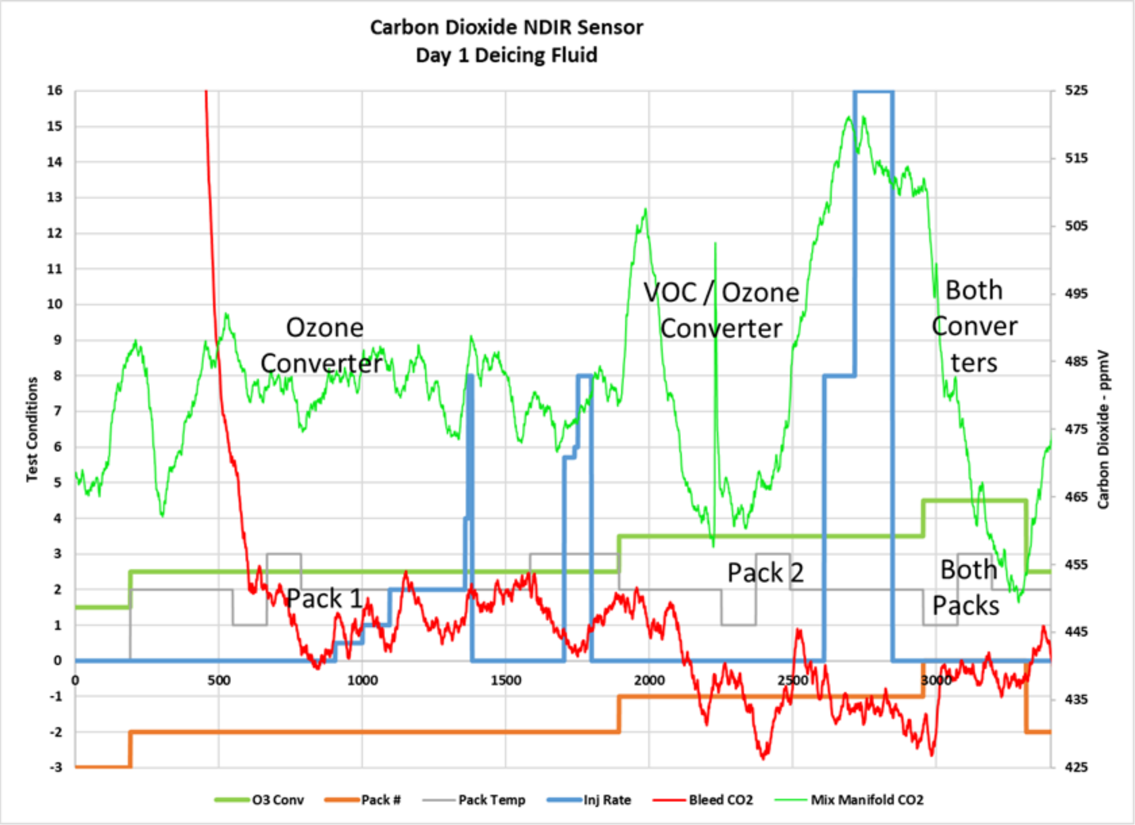


Figure 141. Carbon dioxide sensor response to deicing fluid (NDIR) day 1

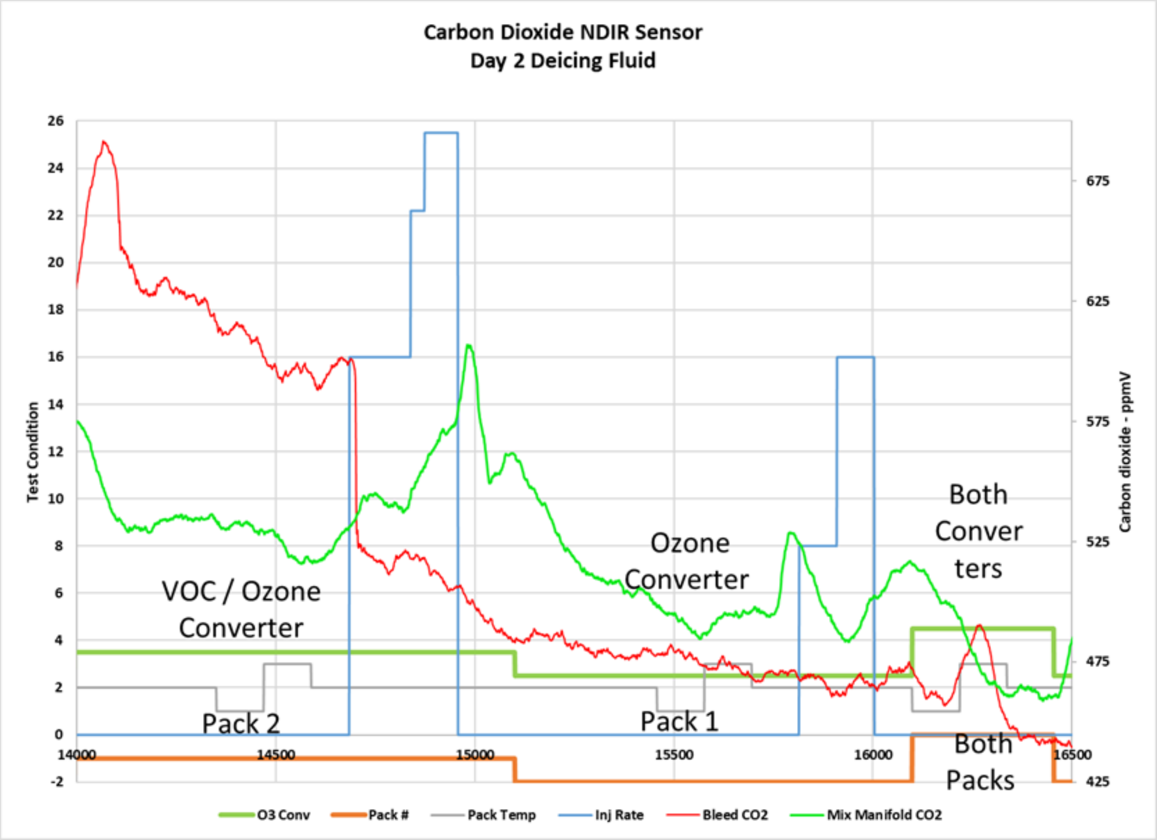


Figure 142. Carbon dioxide sensor response to deicing fluid (NDIR) day 2

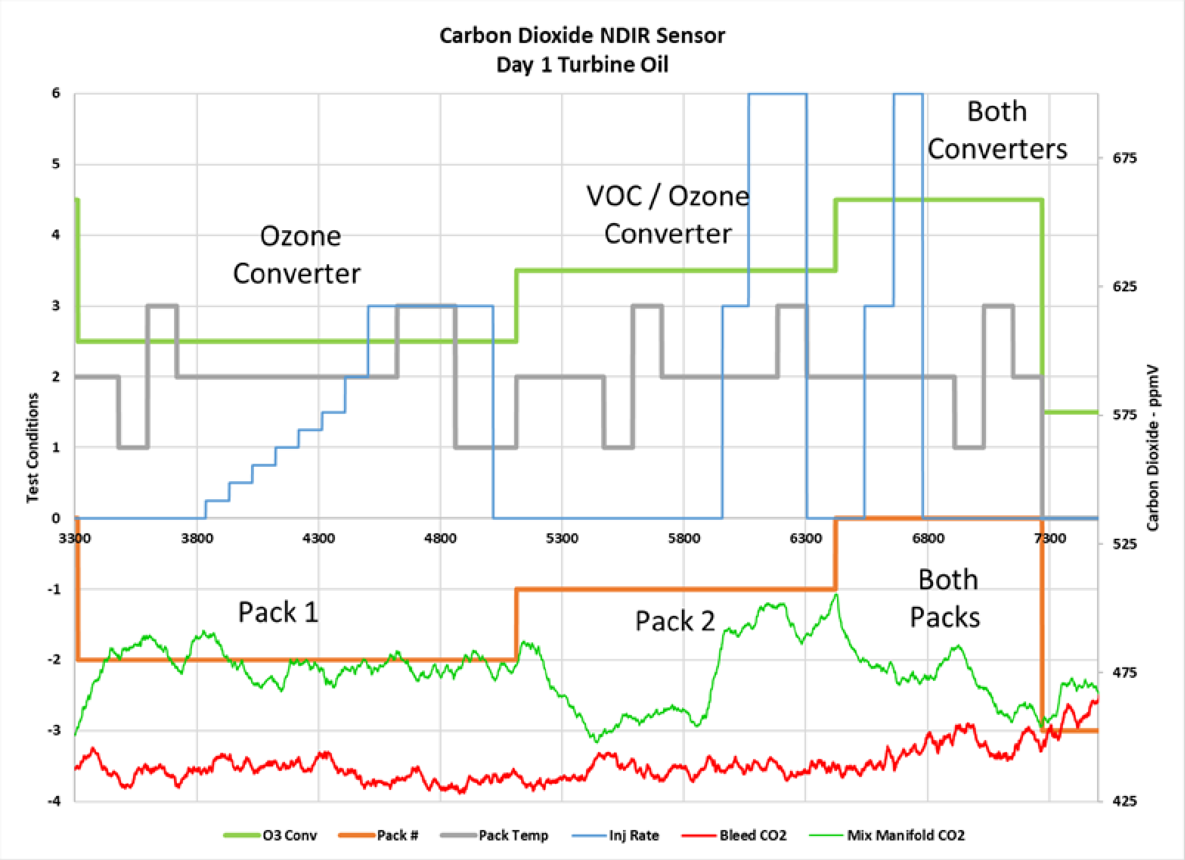


Figure 143. Carbon dioxide sensor response to turbine oil (NDIR) day 1

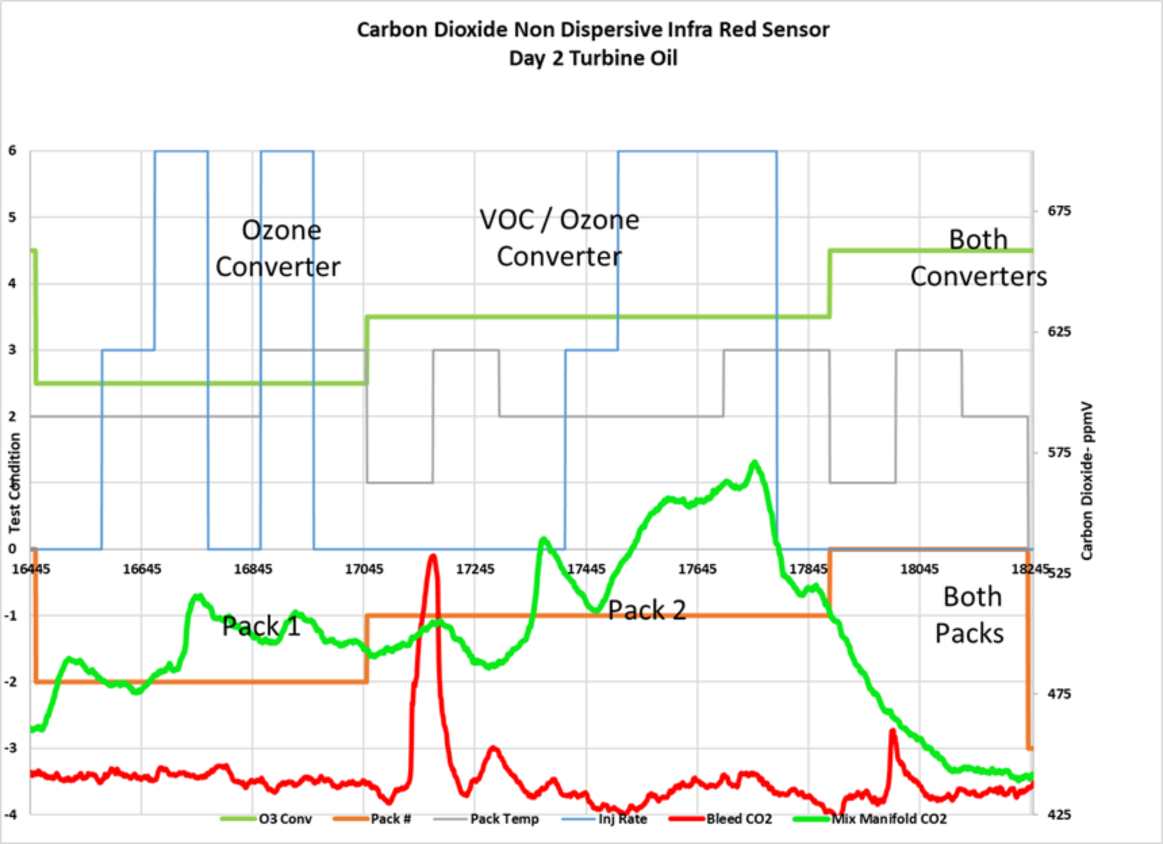


Figure 144. Carbon dioxide sensor response to turbine oil (NDIR) day 2

4.5.5 Hydrogen sulfide (electrochemical sensor)

Hydrogen sulfide sensor response to deicing fluid ingestion is presented in Figure 145 and Figure 146. The findings from these charts are as follows:

- Deicing fluid injection does not produce a repeatable hydrogen sulfide electrochemical sensor response, although it appears there may be a trend in the response that aligns with the change in ingestion rate of deicing fluid.
- Increasing or decreasing pack temperature while injecting deicing fluid does not influence the sensor response.

Similarly, hydrogen sulfide electrochemical sensors do not create a repeatable response to changes of ingestion rate of turbine oil (Figure 147 and Figure 148). The sensor may be sensitive to products released from heat exchangers when pack temperature varies during ingestion of turbine oil.

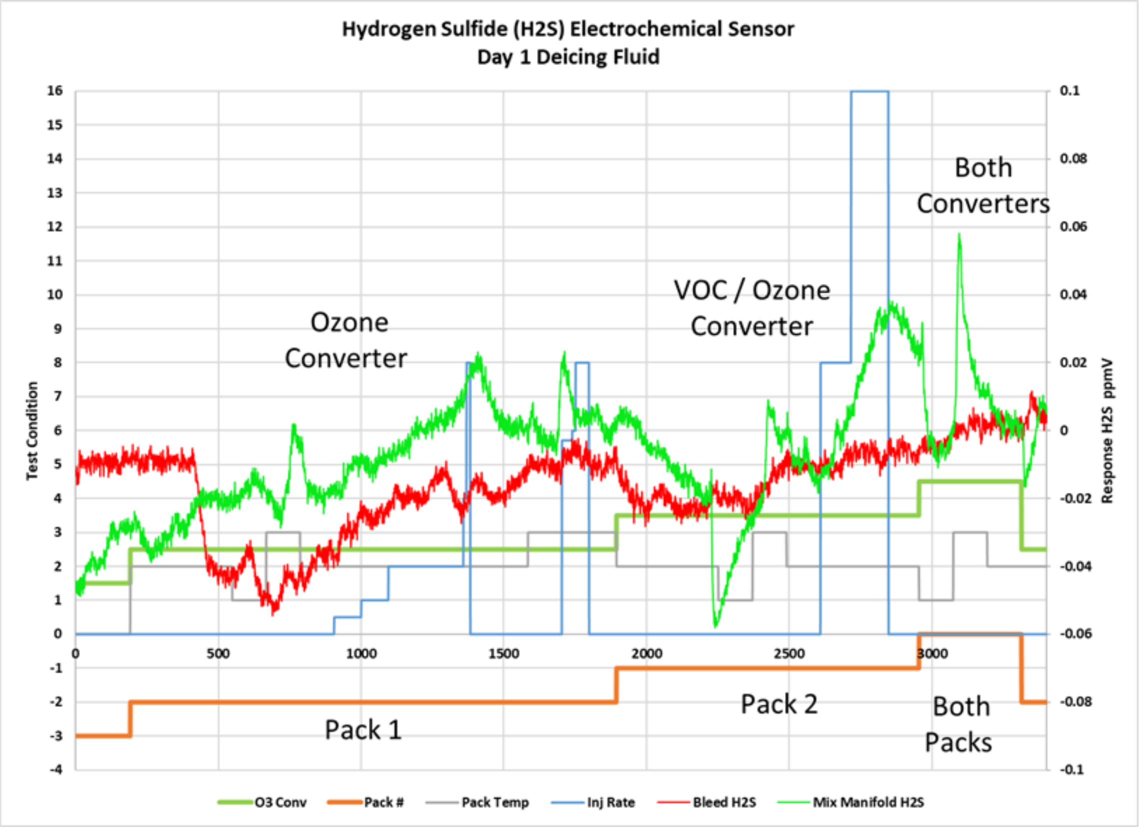


Figure 145. Hydrogen sulfide (H_2S) sensor response to deicing fluid (EC) day 1

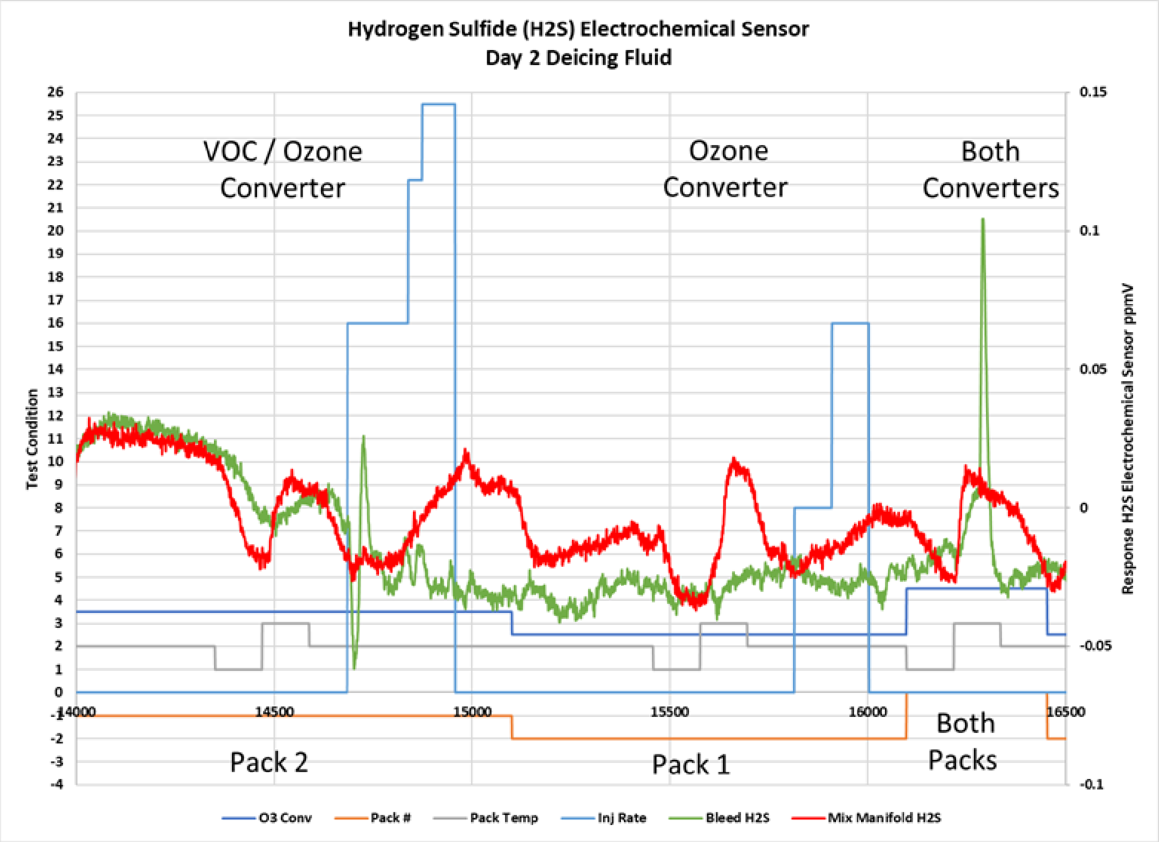


Figure 146. Hydrogen sulfide (H_2S) sensor response to deicing fluid (EC) day 2

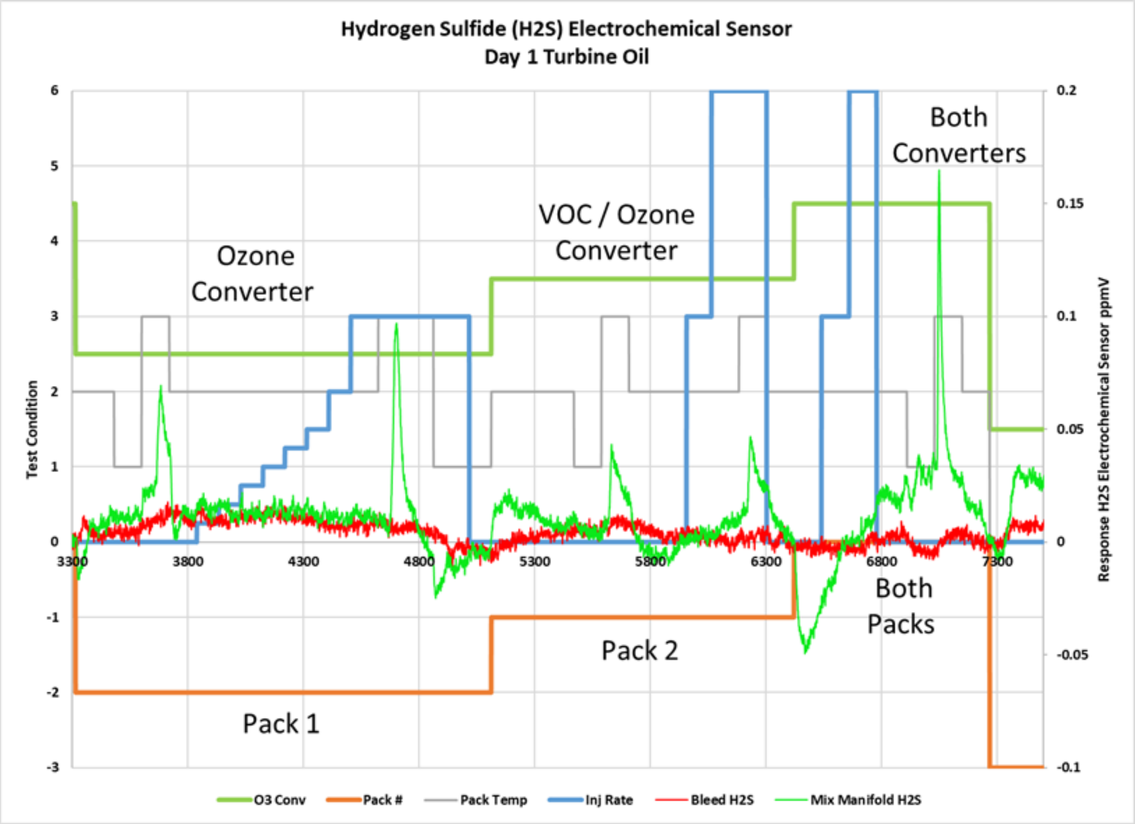


Figure 147. Hydrogen sulfide (H_2S) sensor response to turbine oil (EC) day 1

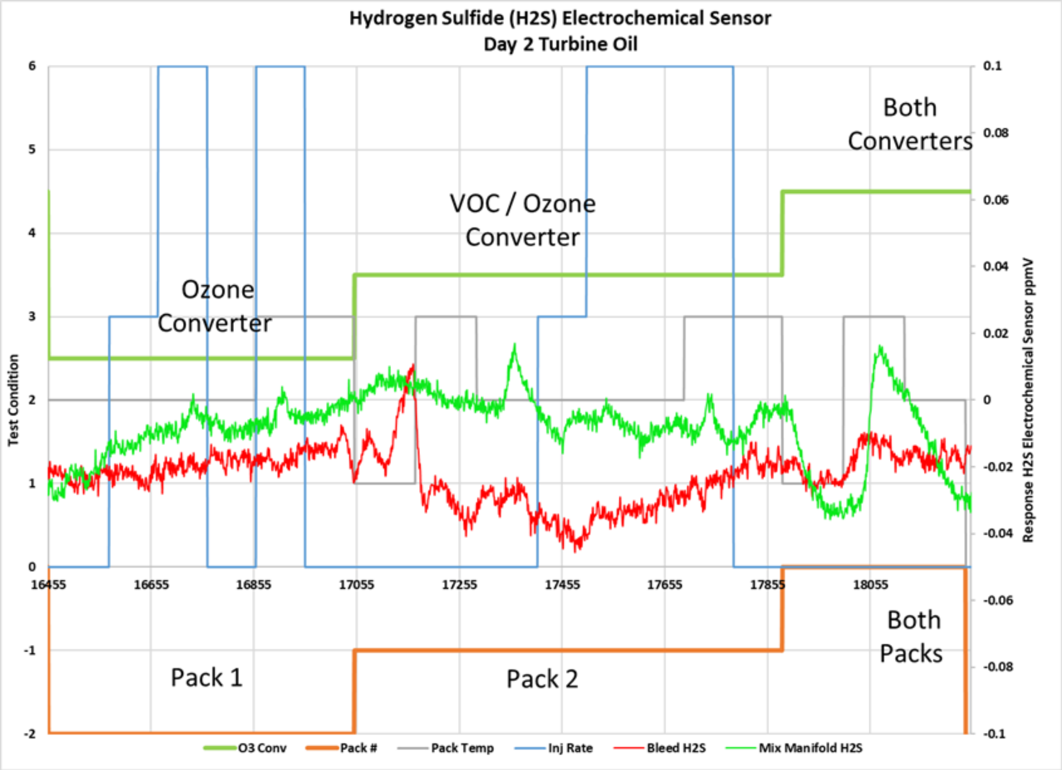


Figure 148. Hydrogen sulfide (H_2S) sensor response to turbine oil (EC) day 2

4.5.6 Volatile organic compounds (VOC) by metal oxide sensor (MOS)

VOC metal oxide sensor (MOS) response for deicing fluid ingestion is presented in Figure 149 and Figure 150. The findings from these charts are as follows:

- There is much more response of a MOS to deicing fluid upstream of the ozone converter than at the mix manifold.
- Increasing or decreasing pack temperature while injecting deicing fluid does not change response.

VOC sensor response with a MOS for turbine oil ingestion is presented in Figure 151 and Figure 152. The findings from these charts are as follows:

- Turbine oil does not cause a measurable sensor response at the injection rates tested for the type of MOS that was tested.
- Metal oxide sensor type is an important criterion for metal oxide sensor performance.

Results from May 2022 testing indicated that some MOS sensor types do respond to turbine oil.

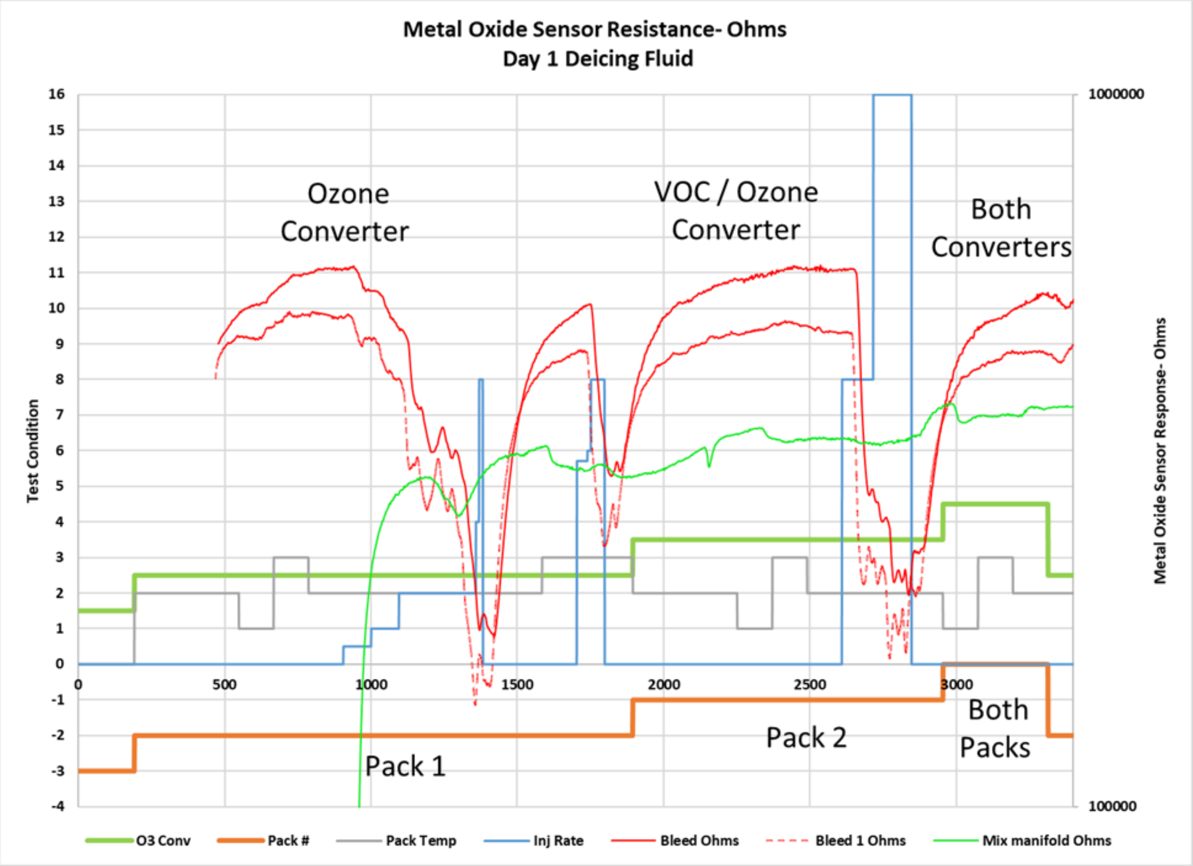


Figure 149. VOC sensor response to deicing fluid (MOS) day 1

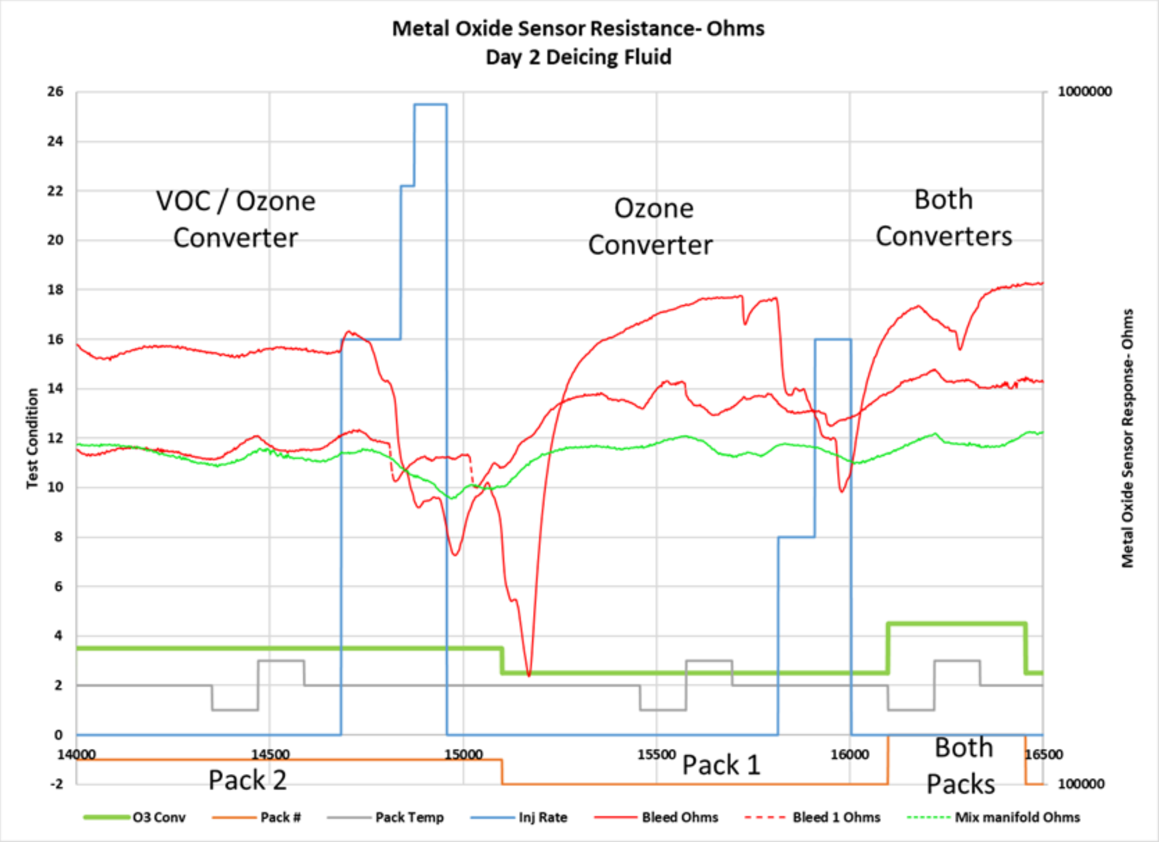


Figure 150. VOC sensor response to deicing fluid (MOS) day 2

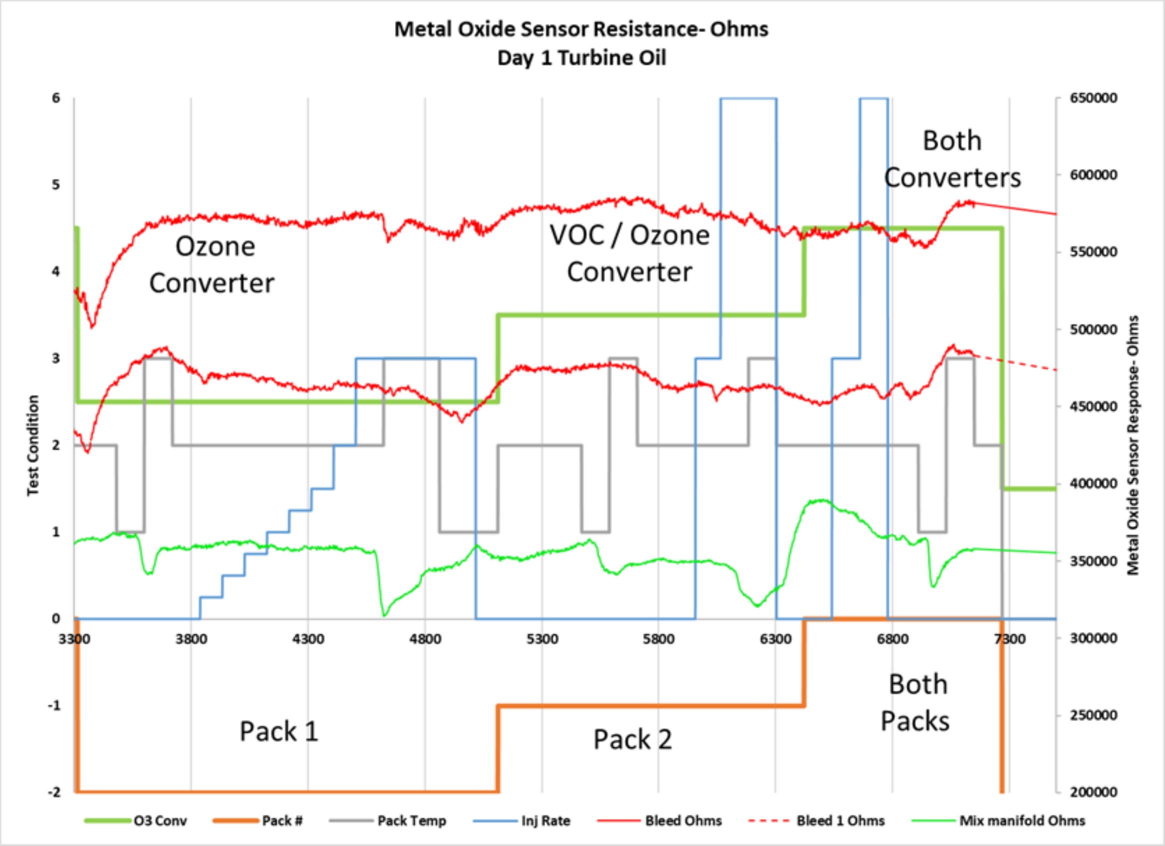


Figure 151. VOC sensor response to turbine oil (MOS) day 1

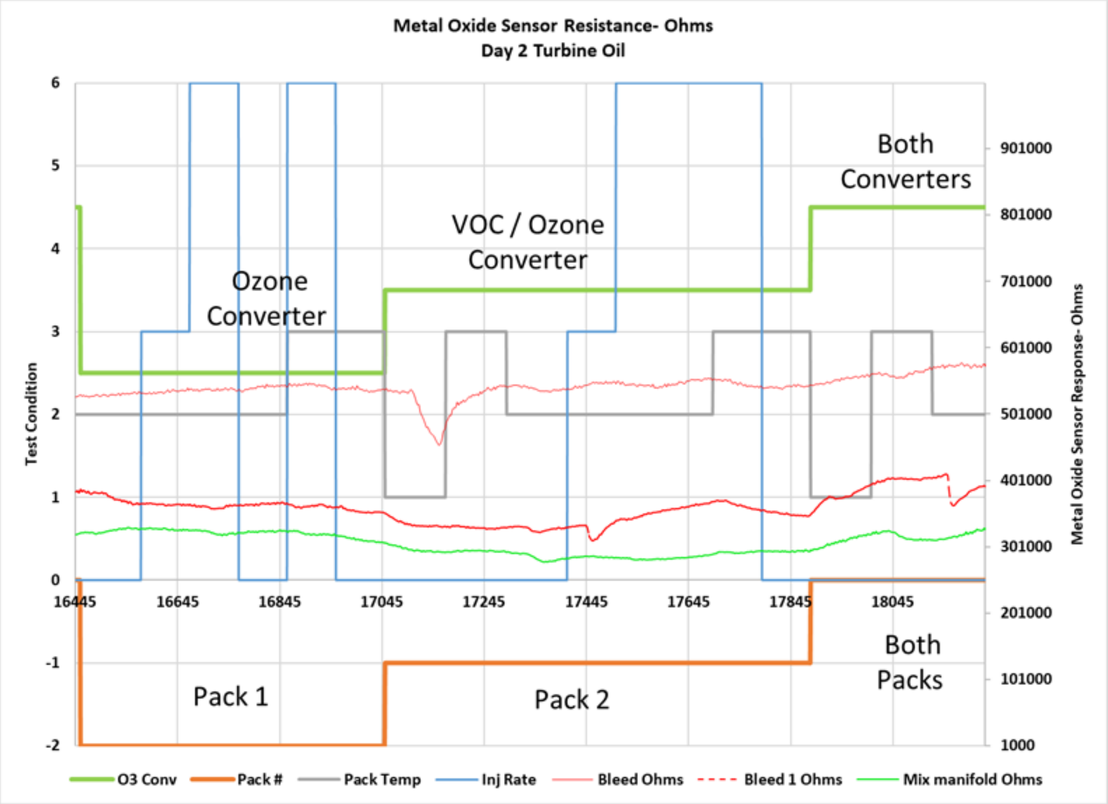


Figure 152. VOC sensor response to turbine oil (MOS) day 2

4.5.7 VOC by photoionization sensor (PID)

VOC response by photoionization sensor (PID) for deicing fluid ingestion is presented in Figure 153 and Figure 154. The findings from these charts are as follows:

- Deicing fluid does create a PID sensor response.
- Increasing or decreasing pack temperature while injecting deicing fluid also creates a PID sensor response.

VOC response by PID for turbine oil ingestion is presented in Figure 155 and Figure 156. The findings from these charts are as follows:

- Turbine oil creates a greater response at the bleed air sample location than at the mix manifold sample location.
- Increasing or decreasing pack temperature while ingesting turbine oil appeared to correlate with mix manifold PID sensor response.

The PID sensor measurements were near the PID lower detection limits.

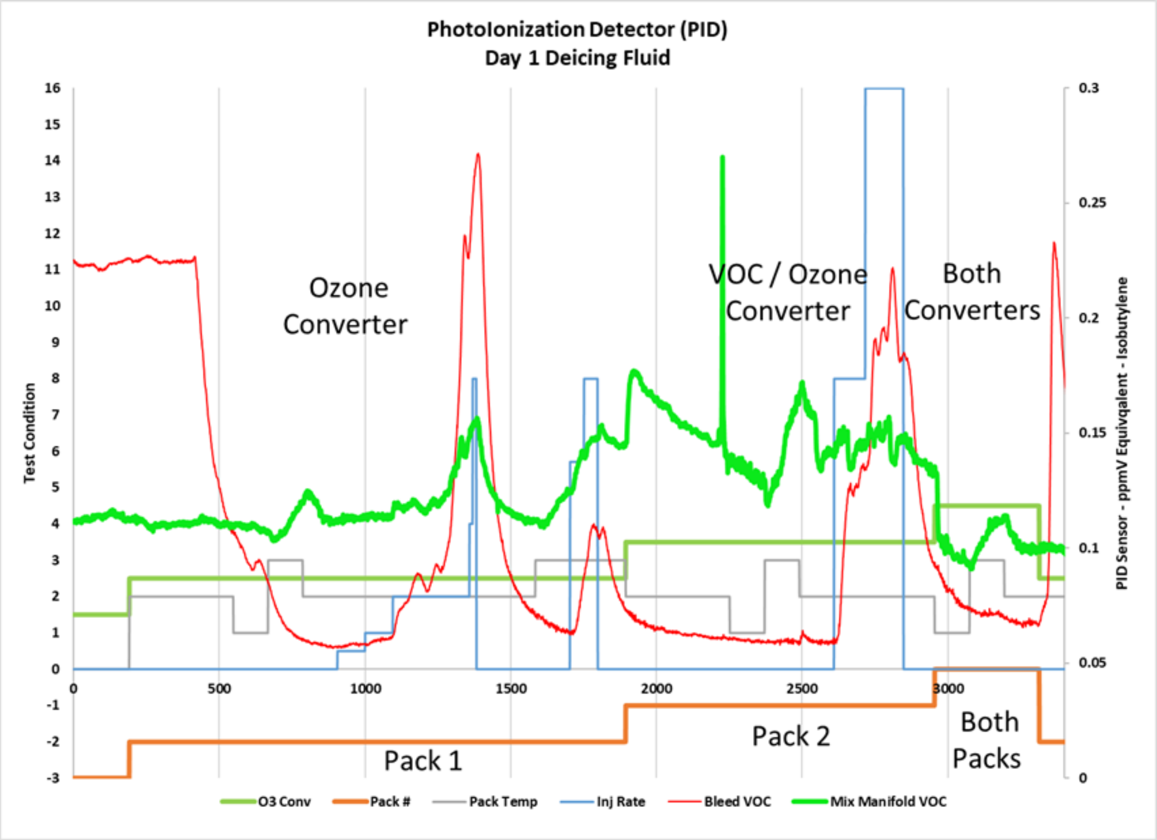


Figure 153. VOC sensor response to deicing fluid (PID) day 1

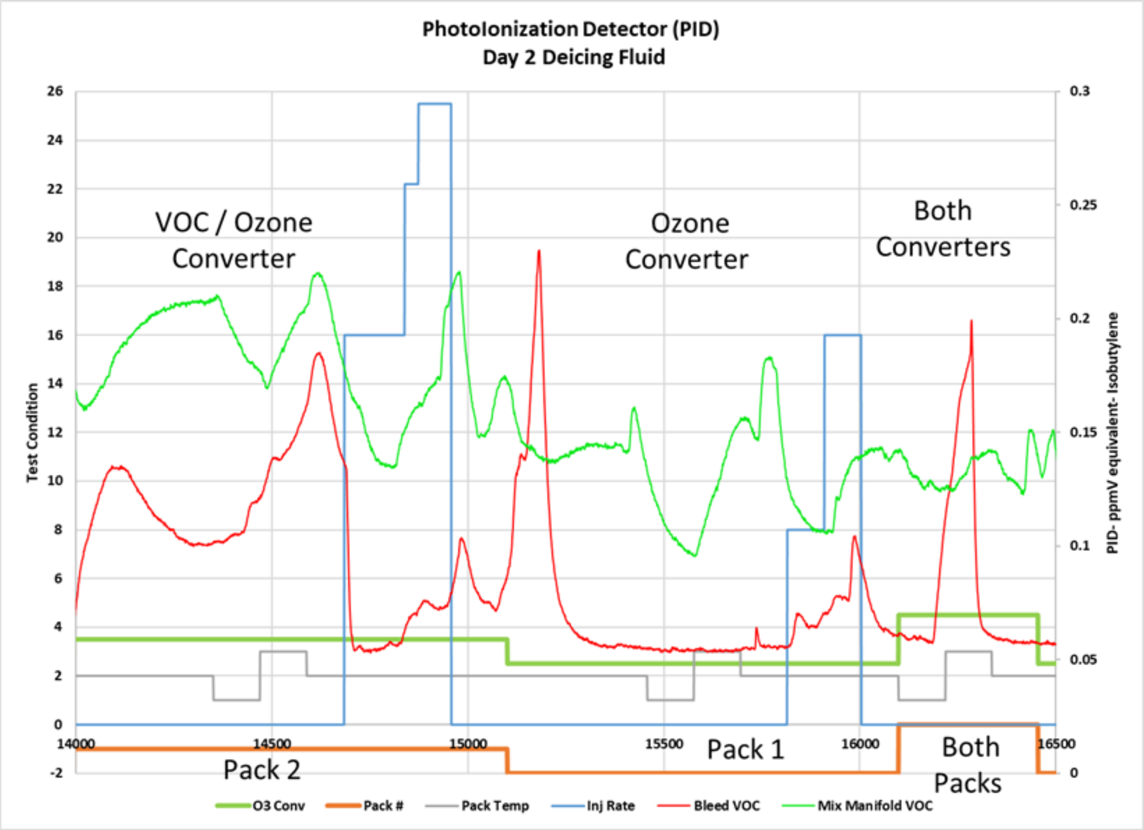


Figure 154. VOC sensor response to deicing fluid (PID) day 2

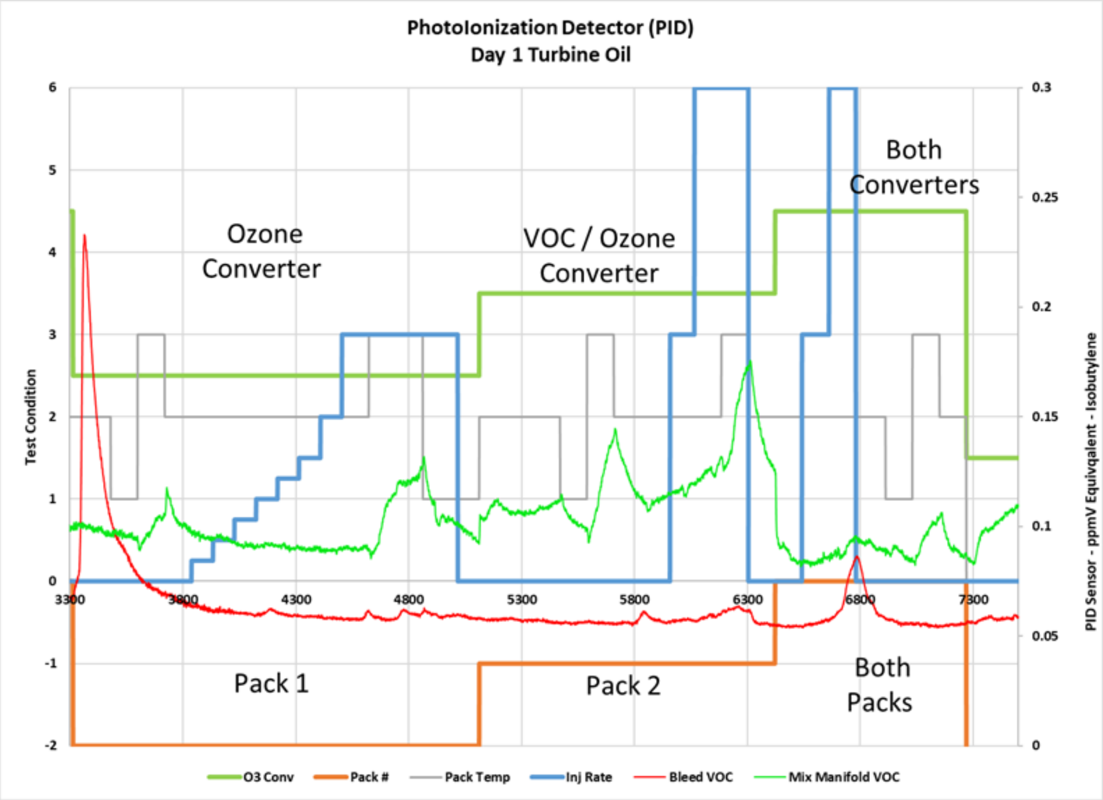


Figure 155. VOC sensor response to turbine oil (PID) day 1

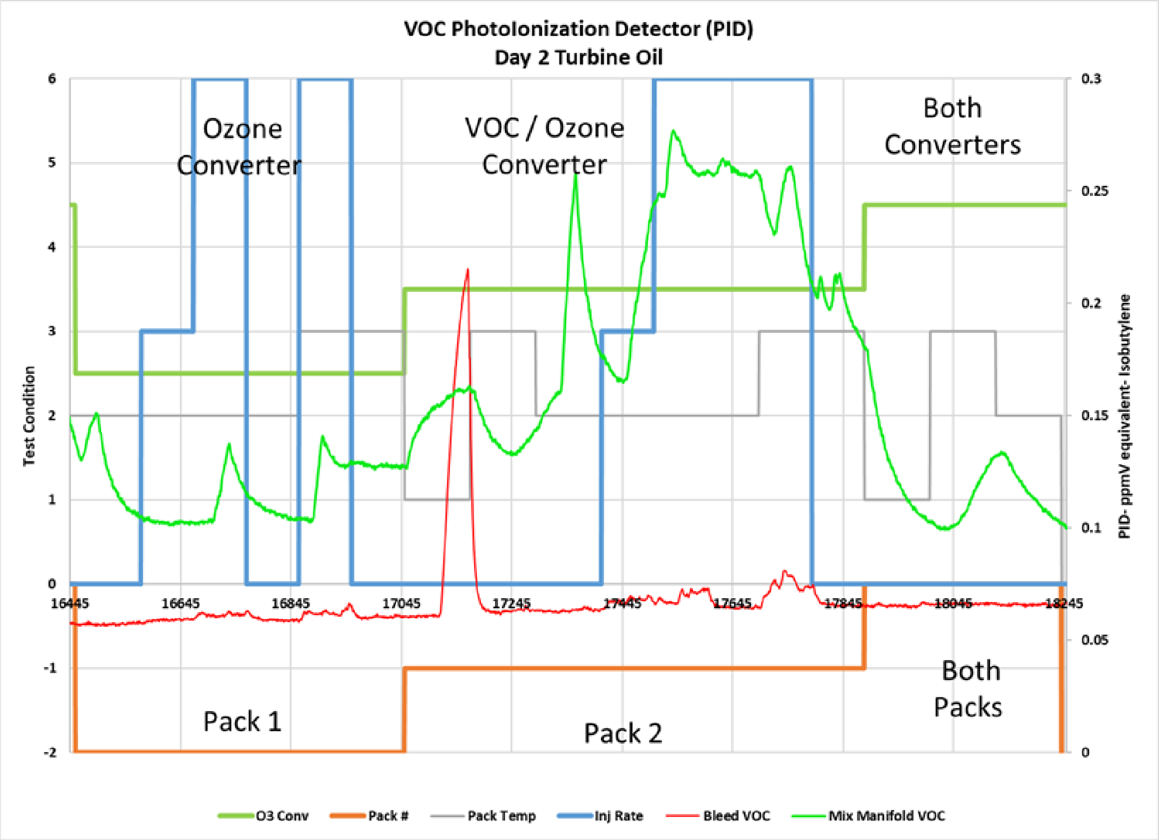


Figure 156. VOC sensor response to turbine oil (PID) day 2

4.5.8 Nitrogen dioxide (NO2) electrochemical sensor (EC)

The nitrogen dioxide sensors had no response to concentration changes of deicing fluid or pack temperature changes when deicing fluid was ingested (Figure 157 and Figure 158). The nitic oxide sensors had no response to turbine oil concentration or pack temperature changes when turbine oil was ingested (Figure 159 and Figure 160).

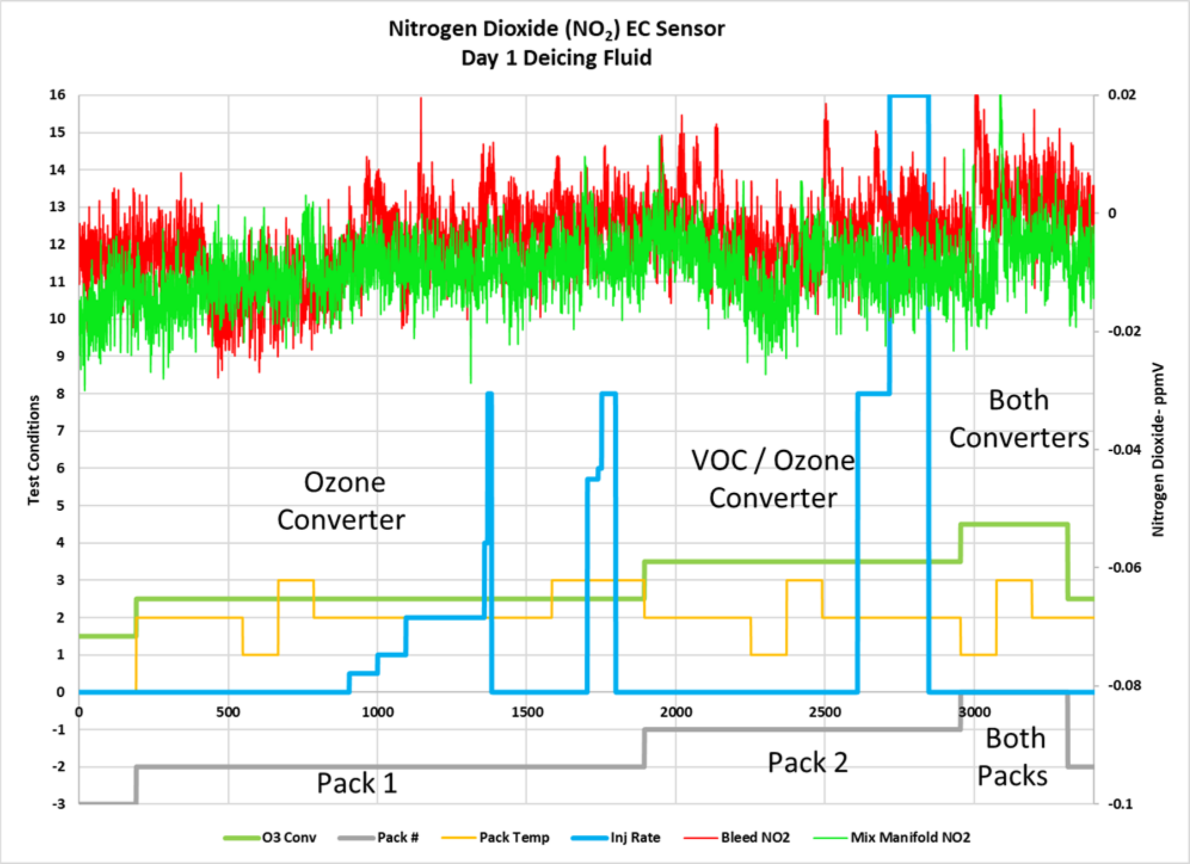


Figure 157. Nitrogen dioxide sensor response to deicing fluid (EC) day 1

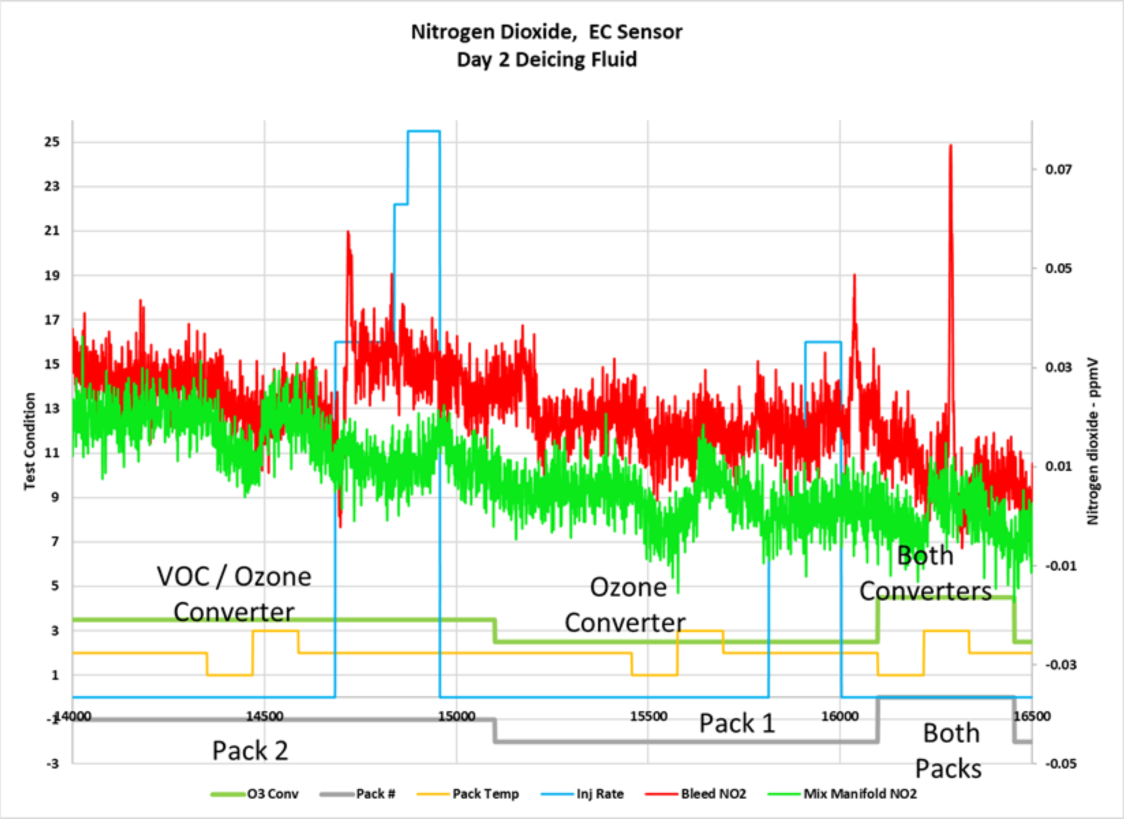


Figure 158. Nitrogen dioxide sensor response to deicing fluid (EC) day 2

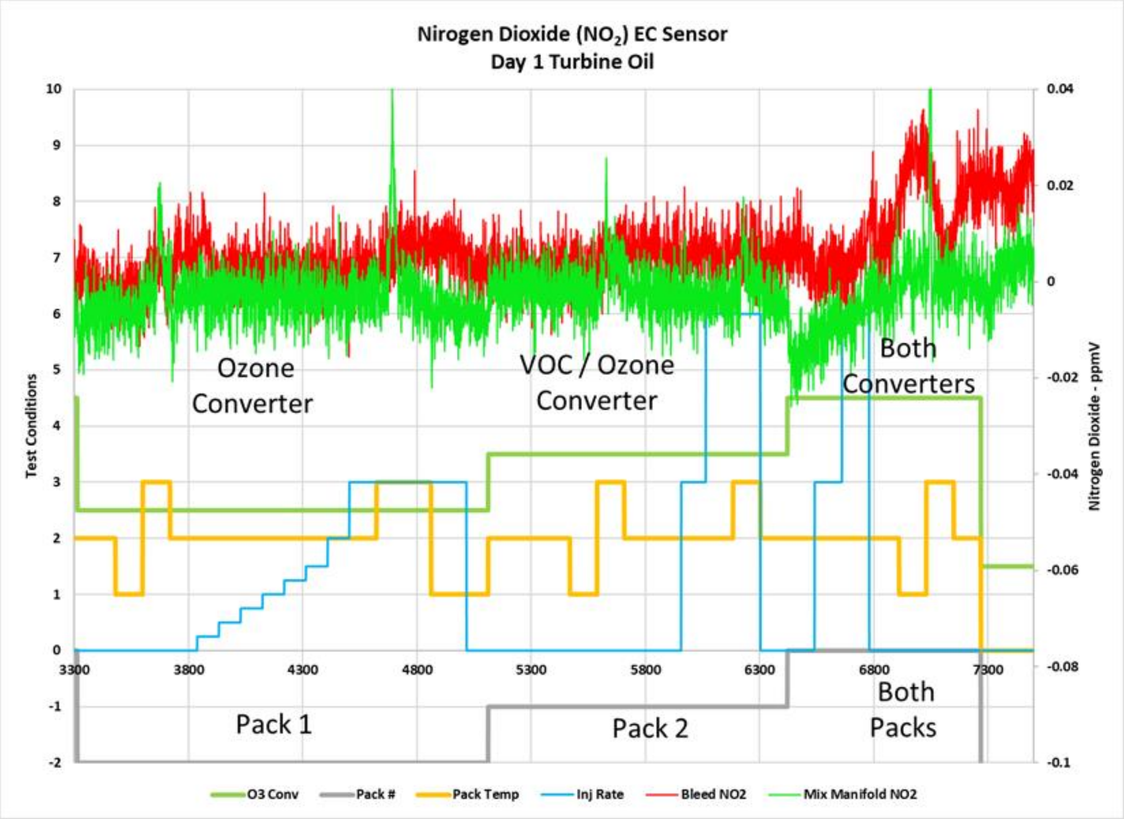


Figure 159. Nitrogen dioxide sensor response to turbine oil (EC) day 1

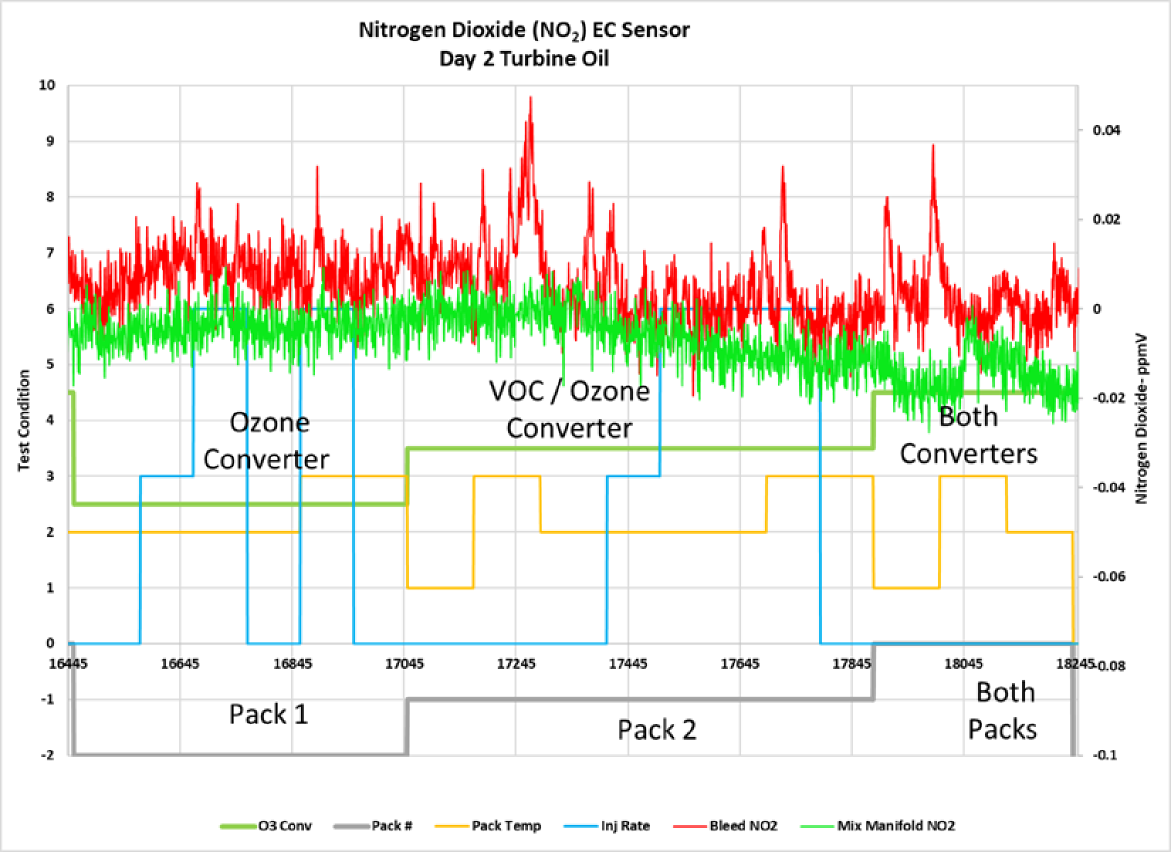


Figure 160. Nitrogen dioxide sensor response to turbine oil (EC) day 2

4.5.9 Nitric oxide (NO) electrochemical sensor

The nitric oxide sensor had no response to concentration changes of deicing fluid or pack temperature changes when deicing fluid was ingested (Figure 161 and Figure 162). The nitic oxide sensor had no response to turbine oil concentration or pack temperature changes when turbine oil was ingested (Figure 163 and Figure 164).

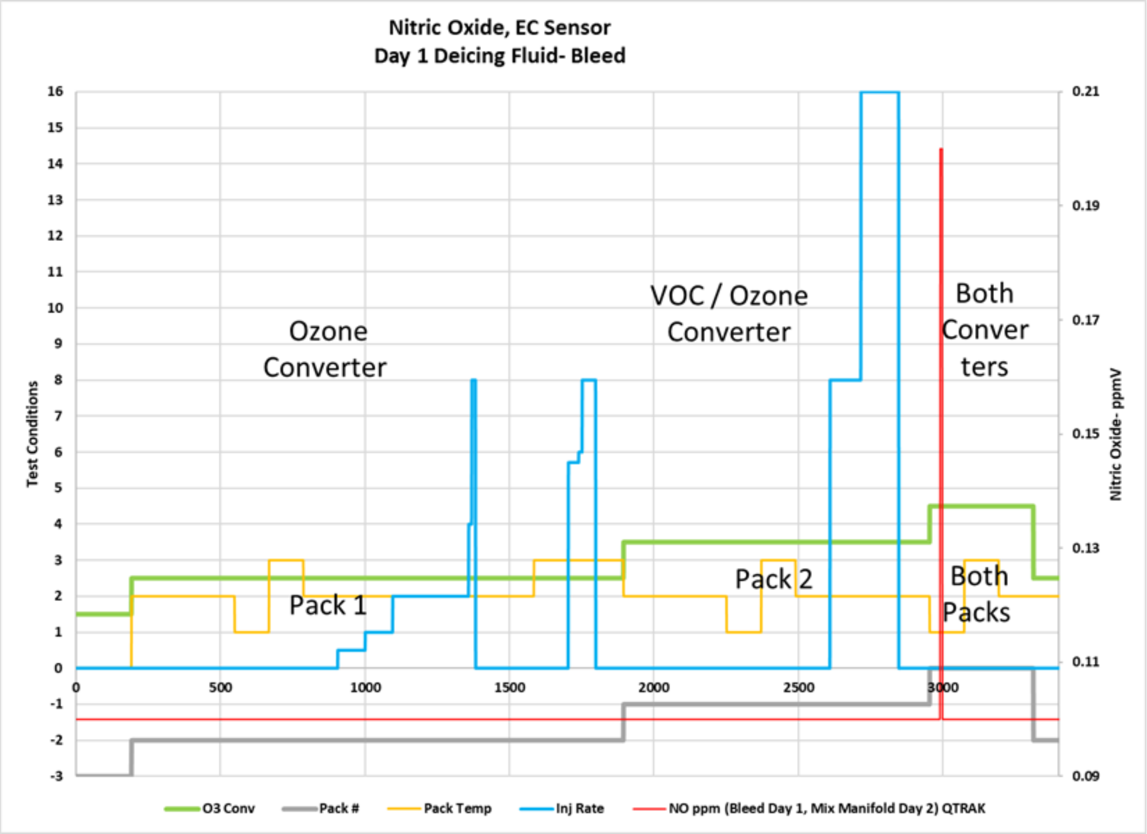


Figure 161. Nitric oxide sensor response to deicing fluid (EC) day 1

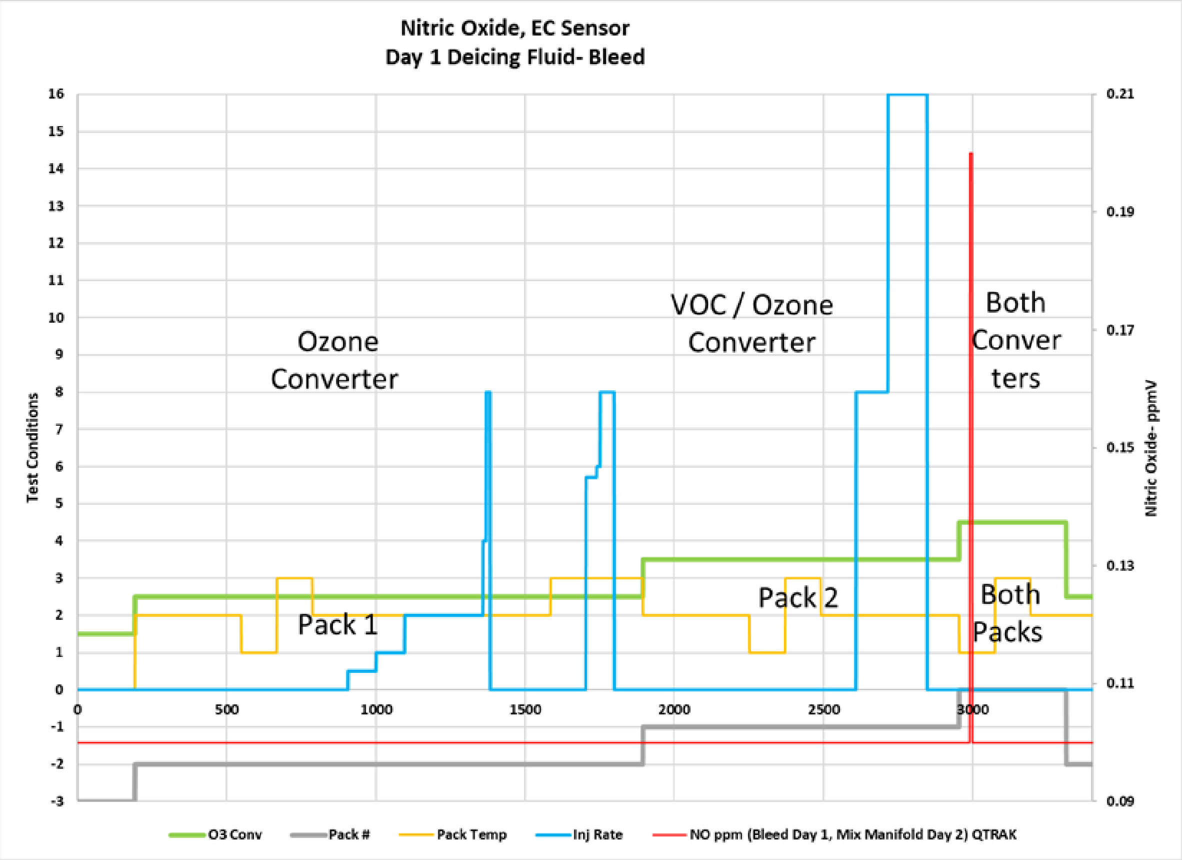


Figure 162. Nitric oxide sensor response to deicing fluid (EC) day 2

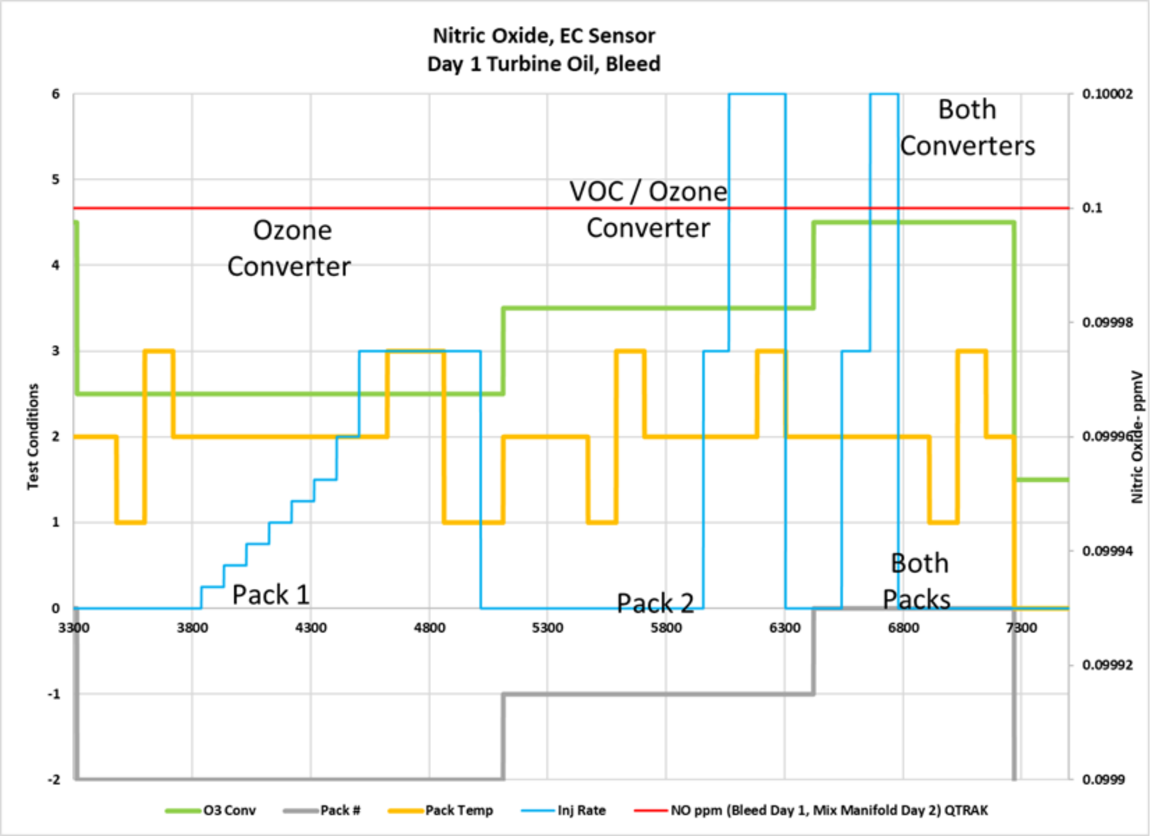


Figure 163. Nitric oxide sensor response to turbine oil (EC) day 1

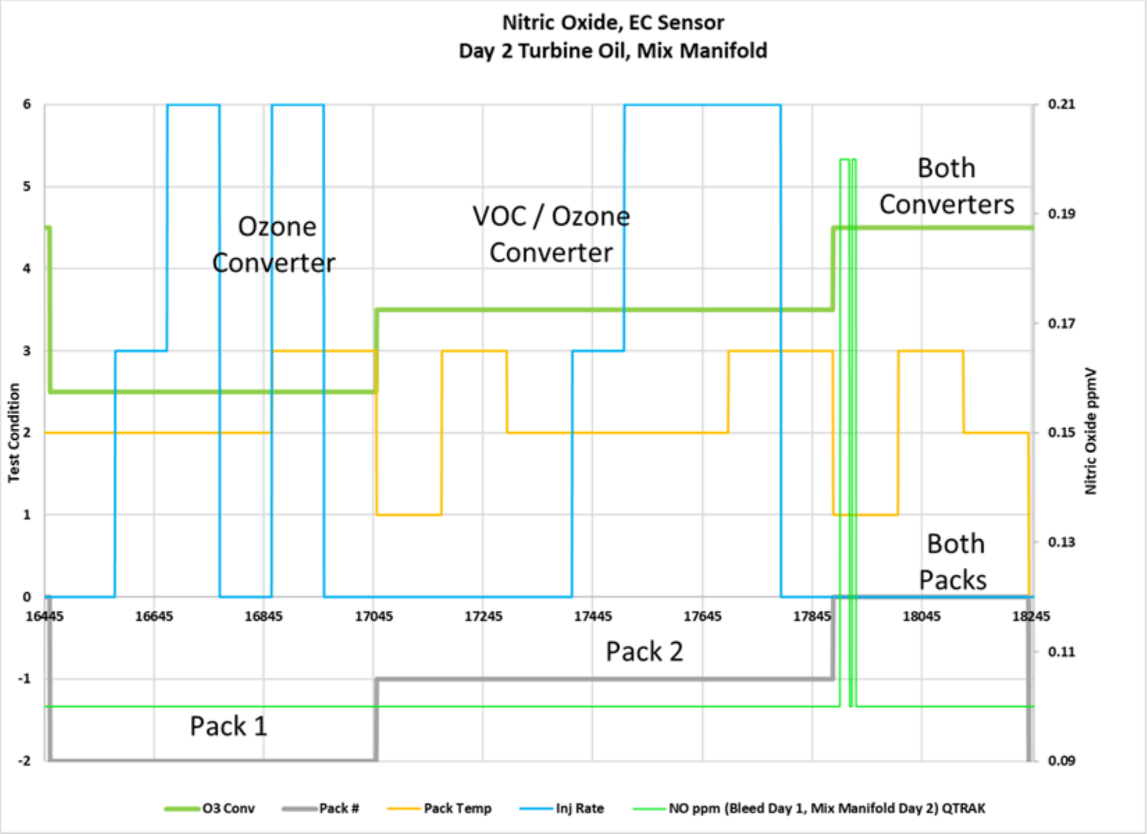


Figure 164. Nitric oxide sensor response to turbine oil (EC) day 2

4.5.10 Ozone (electrochemical sensor)

Ozone electrochemical sensors responded to deicing fluid ingestion concentration, and to a change in pack temperature when deicing fluid was ingested (Figure 165 and Figure 166). The ozone sensors did not appear to respond to changes in concentration of oil but did respond to pack temperature changes during oil injection (Figure 167 and Figure 168).

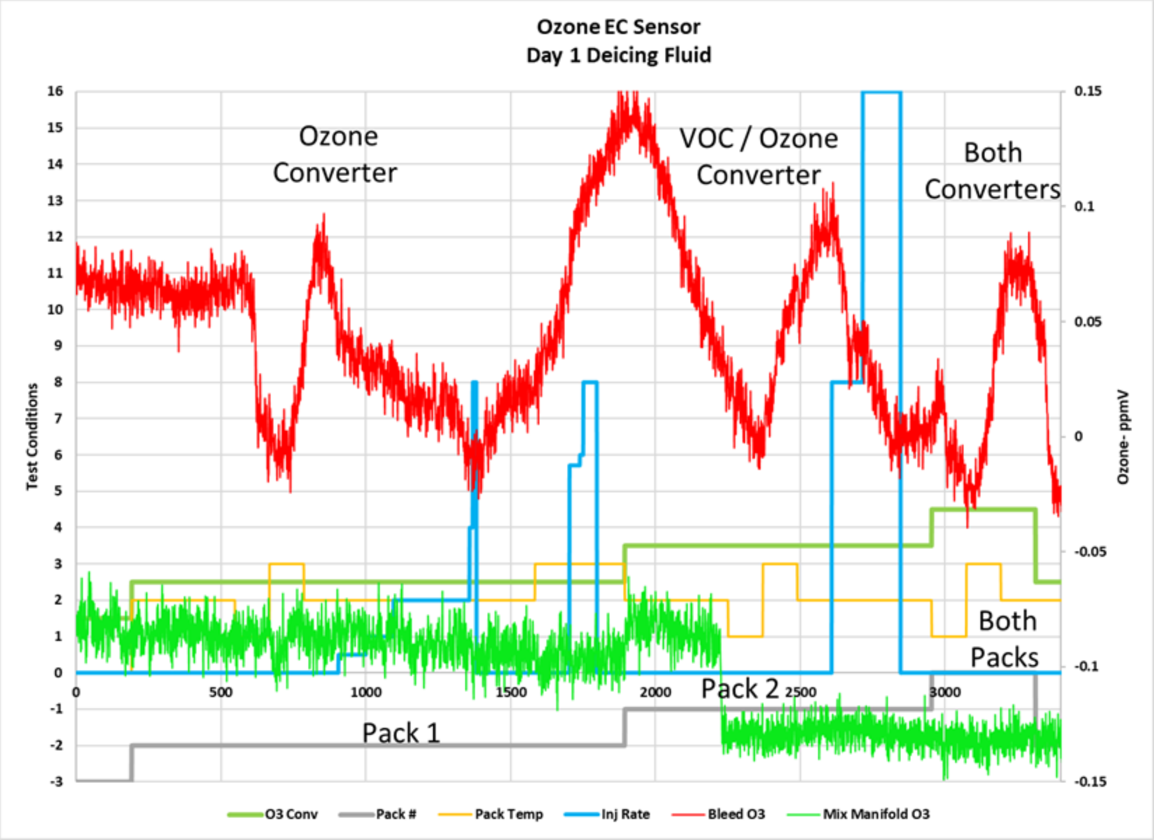


Figure 165. Ozone sensor response to deicing fluid (EC) day 1

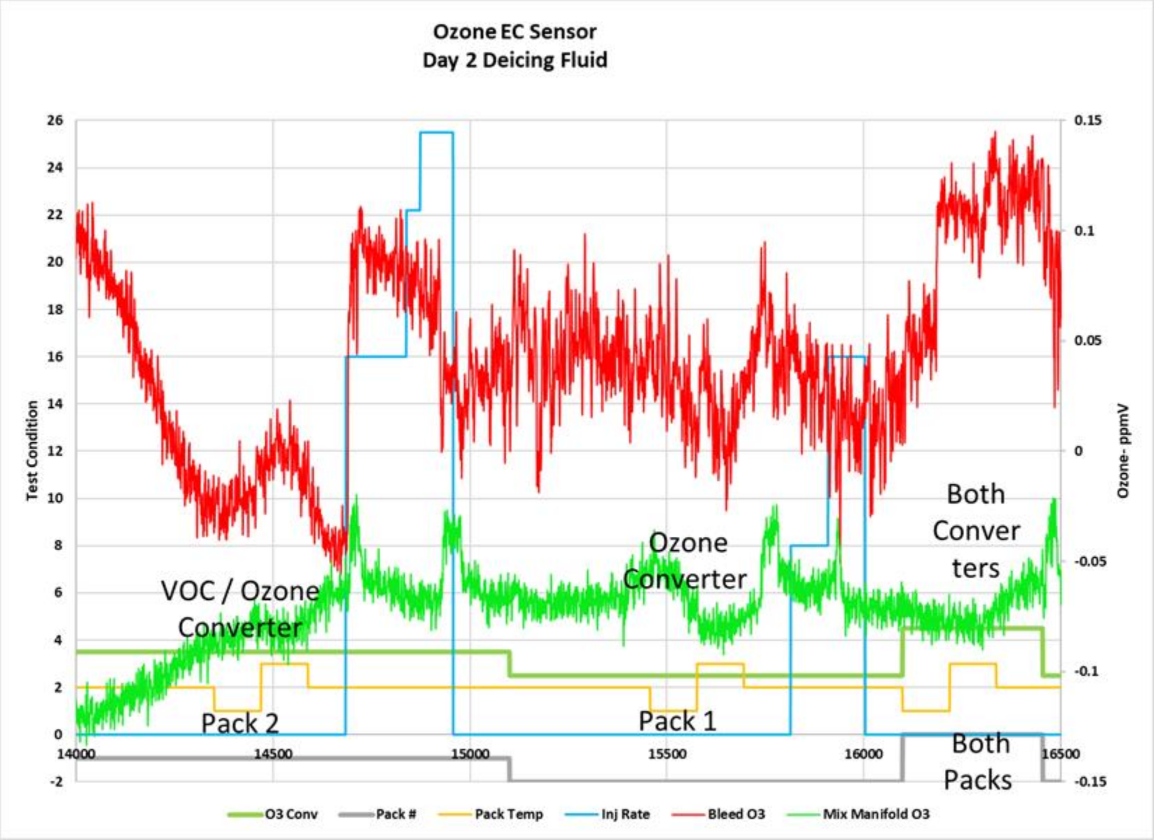


Figure 166. Ozone sensor response to deicing fluid (EC) day 2

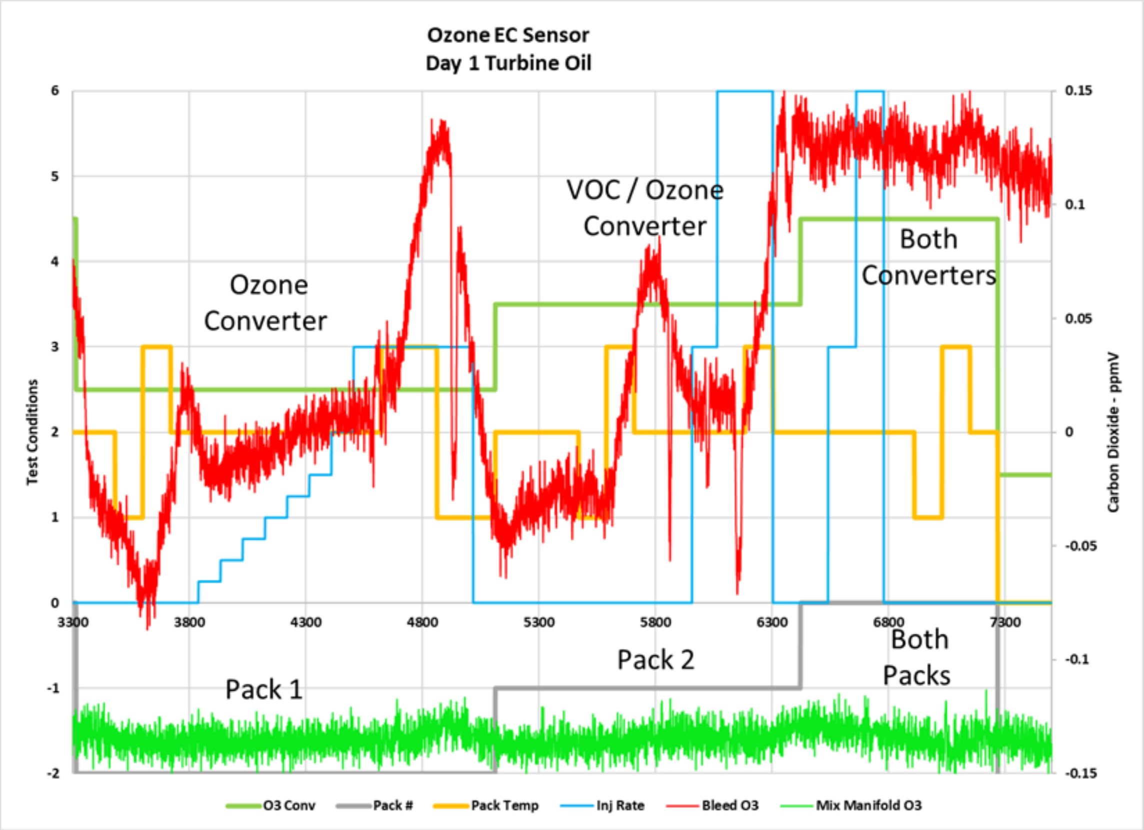


Figure 167. Ozone sensor response to turbine oil (EC) day 1

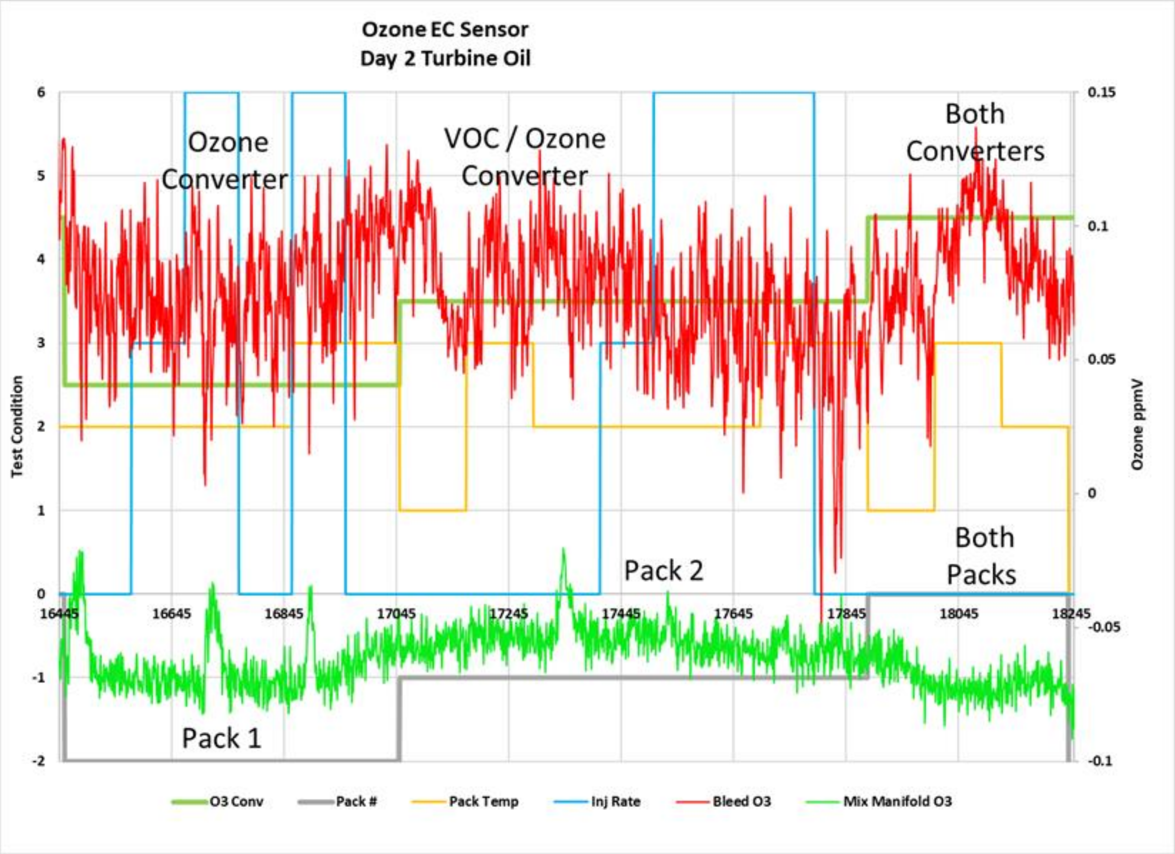


Figure 168. Ozone sensor response to turbine oil (EC) day 2

4.5.11 Formaldehyde (electrochemical sensor)

The formaldehyde electrochemical sensor responded to deicing fluid ingestion concentration changes but did not appear to respond to a change in pack temperature when deicing fluid was ingested (Figure 169 and Figure 170). The formaldehyde sensor did not respond to changes in concentration of oil or to pack temperature changes during oil injection (Figure 171 and Figure 172).

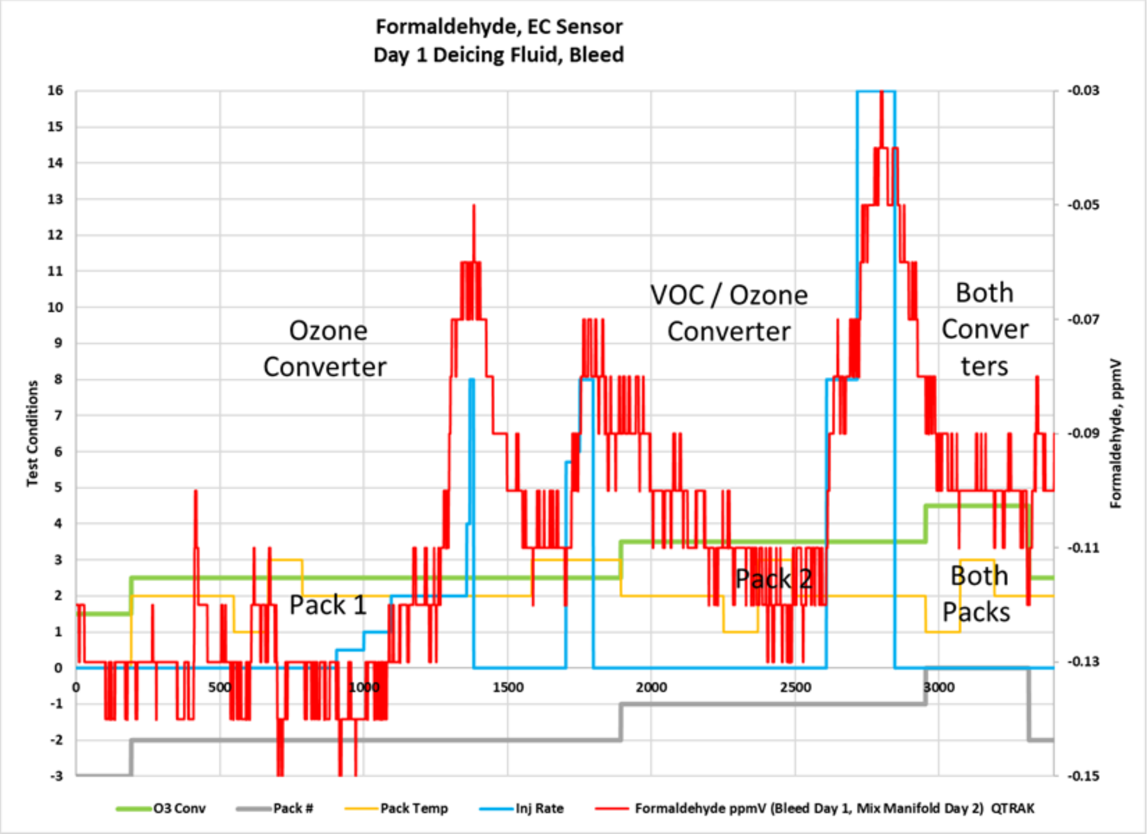


Figure 169. Formaldehyde sensor response to deicing fluid (EC) day 1

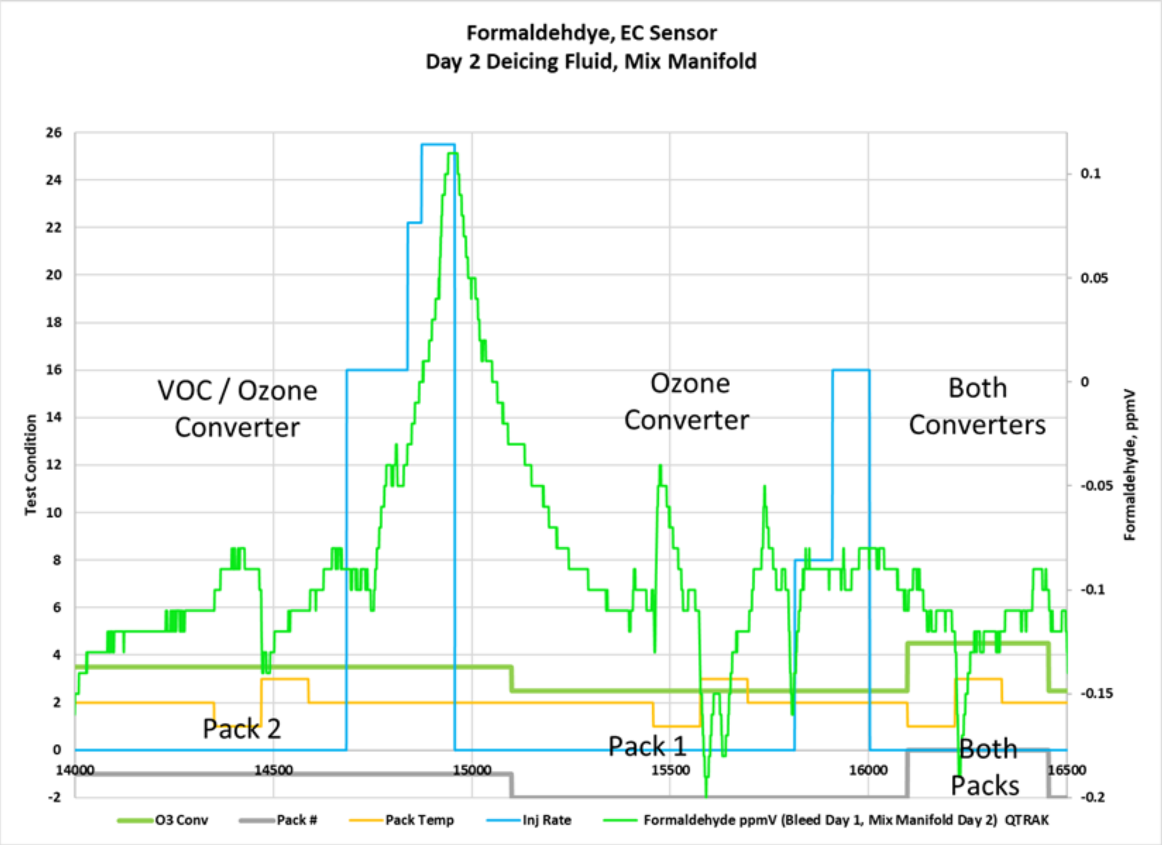


Figure 170. Formaldehyde sensor response to deicing fluid (EC) day 2

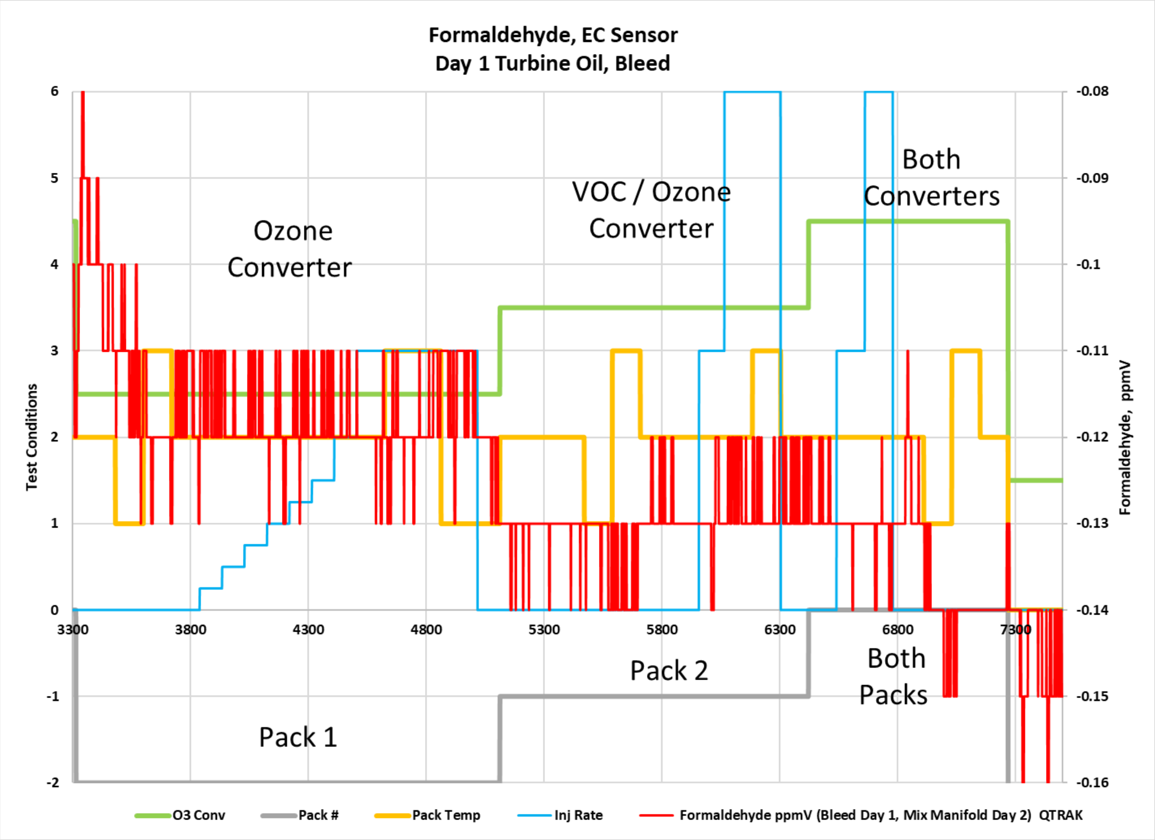


Figure 171. Formaldehyde sensor response to turbine oil (EC) day 1

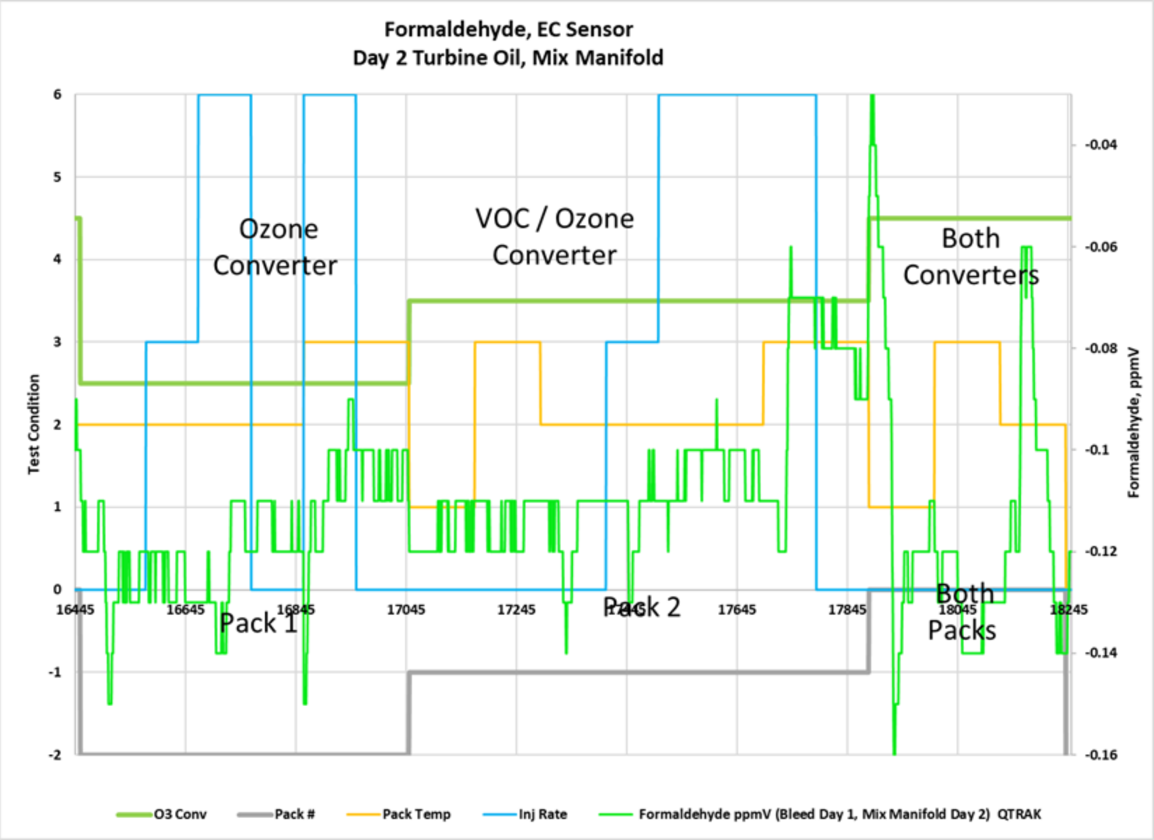


Figure 172. Formaldehyde sensor response to turbine oil (EC) day 2

4.5.12 Griffin G510® Portable Mass Spectrometer

The Griffin G510 utilizes an adsorbent tube to concentrate sample and then desorbs the concentrated sample onto a gas chromatographic column. The instrument is calibrated using a blend of calibration gases that are specified in EPA method TO-15. The blend of gases specified are not common to aircraft bleed air contamination, so the instrument did not find significant levels of relevant contaminants that were on the EPA list. The unit did not provide quantitative data that was referenced to an injected standard.

Other challenges with this method that were observed are that contaminants such as ethanol that are present at high levels must be concentrated using very small volumes of sample, while trace contaminants require large volumes of air to be concentrated to obtain semi-quantitative information. Sampling and test procedures should be developed before the unit is placed in the field to obtain aircraft bleed air measurements.

The Griffin G510 report may be found in Appendix H. Seventeen of 35 Tedlar® bags contained identifiable compounds. Hexane was the most identified compound in the samples of inlet air and bleed air.

4.6 American Airlines test conclusions

4.6.1 Air treatment

The human olfaction testing was not able to be confirmed with the instruments that were available to measure VOC contaminants on the aircraft. When testing with the ozone converter, and number 1 ECS pack, the olfaction level with deicing fluid was determined to be at 8 ml/min injection. The Griffin GC/MS confirmed the presence of ethylene & propylene glycol in cabin, but the UFP level was not significantly changed (max ~7000 particles / cubic centimeter).

The olfaction level with oil determined to be at 3 ml/min injection. Compounds from oil were below the level of detection for the Griffin G510 GC/MS. The UFP level increased (max ~40,000 particles/cubic centimeter). When testing with the VOC/Ozone converter and number 2 ECS Pack, the olfaction level with deicing fluid was determined to be greater than 16 ml/minute ingestion rate. The Griffin G510 GC/MS confirmed the presence of ethylene & propylene glycol in cabin. The UFP level was not significantly changed (max ~7000 particles per cubic centimeter). The olfaction level with oil determined to be at 6 ml/min injection. Compounds from oil were below level of detection for the Griffin G510 GC/MS. The UFP levels significantly increased (max ~2,800,000 p/cc).

Odor observations indicated that the Number 2 ECS pack, complimented with the VOC/ozone converter required a greater ingestion rate to achieve detectible odors deicing fluid and turbine oil. The testing could not determine if the increased levels of UFP levels originated in the VOC/ozone converter, or the ECS pack.

The most responsive VOC sensor type of those utilized during this test for detection of deicing fluid was the photoionization sensor. Metal oxide sensors also responded to deicing fluid at the concentrations tested. The most responsive UFP sensors for detection of turbine oil contamination were the corona discharge UFP sensors. The challenge with the corona discharge sensors is that they are known to be over-ranged at the particle concentrations of oil that are generated during a contamination event. However, the corona discharge sensors do appear to be useful to identify that an event has occurred, since the change in particle number is orders of magnitude over numbers measured in normal operation. Other sensor types had minimal response to contaminant concentrations that were ingested by the APU.

5 Executive discussion

Test stand results consist of laboratory chemical analytical results for aldehydes, volatile organic compound results for samples acquired from summa canisters and adsorbent cartridges, and semivolatile samples captured from quartz filters and glass cartridges with adsorbent media consisting of a layer of XAD resin sandwiched between two layers of polyurethane foam. Tedlar® bags were used to capture samples and ship to Teledyne FLIR for TO-15 semiquantitative analysis using GC/MS analysis of compounds on the EPA TO-15 hit list.

5.1 Results: Real time sensor capability to detect contaminants

There were a range of sensor technologies for particulates and VOCs. The sensor response discussion will focus more on comparative results. Data for each sensor are available in the supporting dataset for this report.

Particle sensors lent themselves well to UFP and PM Comparisons. Formaldehyde CRDS and electrochemical sensors also were compared, and revealed significant findings between CRDS, electrochemical sensors, and laboratory findings. Several methodologies were evaluated for total VOC. Other sensors that were in several of the sensor packages also provided opportunity for a study to see if they might have a response to the test mixture, rather than just to the analyte for which they were calibrated.

5.1.1 Ultra-fine particle sampling results

5.1.1.1 SMPS (UFP), Naneos Partector II (UFP), Ionization Smoke Detector (UFP), APS (PM), Piera (PM) Comparison

Data were normalized for UFP and PM sensors to enable plotting response across the broad range of concentration measurements. The TSI 3375 (UFP) and TSI 3321(PM) are considered as primary measurement methods by which other techniques are compared. They are laboratory grade instruments and suitable instruments for placement in an on-wing environment, should show similar response in direction, but not necessarily magnitude to the contaminant aerosol.

On May 16, 2022, with Eastman 2389®, the Naneos Partector II® tracked almost perfectly with the TSI SMPS both in terms of trends and values (Figure 39). However, on the 17th with Mobil Jet II, it did not track quite as well. The Partector tends to drop off with time and then steps down with increasing bleed temperature while the SMPS does not. Most striking is the large increase with the Partector when injection is stopped while the SMPS drops off rapidly as would be expected (Figure 40). The Naneos Partector II appeared to respond well on May 18, 2022, during the injections of hydraulic fluid (Figure 41).

The anomaly occurred again on May 19th with Mobil Jet II (Figure 42) and again on May 20th with the injection of Mobil Jet II (Figure 43). The total UFP counts decreased when Mobil Jet II concentration increased during these anomalous events. When oil injection ceases, the size distribution moves to smaller and smaller diameters. Likewise, the lower the injection rate, the smaller the sizes. It appears the Partector is more sensitive to smaller particles, or the larger particles somehow suppress the count. This would explain the bump at the end and the decrease with increasing contamination but does not explain the decrease with time. The bump at the end is seen in every case with Mobil Jet II but not with Eastman 2389 on the 16th and Mobil 387 on the 17th. We do not know the reason behind the difference in the two sensing methods. Naneos examined the raw data files from the three Partector units and informed KSU that the anomalies were a result of the high quantity of UFP swamping the corona discharge wire. It appears that this is not a permanent condition, as the unit was able to recover during the cleanout operations between baseline samples.

Other observations from the PM sensor comparison include:

1. The Piera sensor trends track very closely with the APS. The APS gives results in units of particles per CC and the Piera results are in units of particles per liter. If you divide the Piera results by 1000, the values are similar.
2. The smoke detector trends track pretty much with the SMPS, just much smaller signal to noise ratio. The smoke detector baseline shifts from day to day. The ionic sensor is sensitive to temperature, humidity, and pressure. We do not have sufficient data from the modified smoke detector to understand what drives the sensor baseline shift. If it were to be used for onboard applications, there would need to be a means for regular baseline setting; for example, running HEPA filtered air through it.
3. The smoke detector did surprisingly well on the step increases on the 20th and had a clear response at 1 ppm.
4. The responses to hydraulic fluid and oils are similar both for the APS and the Piera. The SMPS, Partector, and the smoke detector all have minimal response to the hydraulic fluid but a big response to the oils. It may be feasible to detect both oil and hydraulic fluid and to differentiate them using an ultrafine particle detector along with an optical fine particle detector. PM levels at some locations may have a strong effect on the PM baseline. This could confound the ability to use a PM sensor to discriminate between oil and hydraulic fluid, as environmental PM may overwhelm the PM being measured in the bleed air. The research is indicating that for both UFP and PM that a baseline sample should be

compared to a clean healthy engine bleed system, and not to an atmospheric sample of particulate matter entering the engine.

Data is not available for the TSI Nanoscan, as that instrument also was swamped by the high level of particles. During earlier tests the TSI 3007 also was over-range due to its limitation of 500,000 particles per cubic centimeter. The TSI 3775 CPC used in the SMPS would not be able to measure the high number of particles as a standalone instrument. The air must first pass through the SMPS classifier before entering the CPC. The TSI 3080 Electrostatic Classifier separate particles by approximate size and sequentially totalizes the particle numbers in the size bins. It performed well up to the highest levels of contamination used in this test. Total particle count is then derived by summing the quantity of particles in each size bin.

6 Conclusions

The findings of this study include the following:

1. We have much better documentation of the effect of accumulation and release of contaminants (specifically oil) from the heat exchanger surfaces in response to temperature changes. It appears hydraulic fluid does not generate similar behavior.
2. It appears the ultrafine particles associated with oil are the result of condensation and are not generated in the engine. Fine particles for oil and hydraulic fluid are generated in the engine.
3. CO2 was demonstrated to be an effective marker for exhaust ingestion. Ingestion from different vehicles/engines have different characteristics but they all generate appreciable amounts of CO2. Also, we only saw substantial CO in conjunction with vehicle exhaust.
4. Limitations of electro-chemical cell include a high minimum detection limit, and calibration that is performed with pure gases, and not with a mixture representative of the test gas.
5. Gas sensors are very susceptible to confounding from exhaust ingestion.
6. Deposition and release of markers onto and from heat exchanger surfaces play an important role in detection of bleed air contamination by oil.

Supporting data for this report can be accessed with the following link: https://doi.org/10.21949/1528260.

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A Oils and fluids

Figure A- 1. Eastman Turbo Oil 2389

Eastman Turbo Oil 2389 specifications are available at:

https://www.eastman.com/en/products/product-detail?product=71097796&pn=turbo+oil+2389

Figure A- 2. Mobil Jet Oil II

Mobil Jet Oil II specifications are available at:

https://www.exxonmobil.com/en-us/aviation/pds/gl-xx-mobil-jet-oil-ii

Figure A- 3. Mobil Jet Oil 387

Mobil Jet Oil 387 specifications are available at: https://www.exxonmobil.com/en/aviation/products-and-services/products/mobil-jet-oil-387

Figure A- 4. ExxonMobil HyJet IV-A plus Hydraulic Fluid

ExxonMobil Hyjet IV-A plus specifications are available at:

https://www.exxonmobil.com/en/aviation/products-and-services/products/hyjet-iv-a-plus

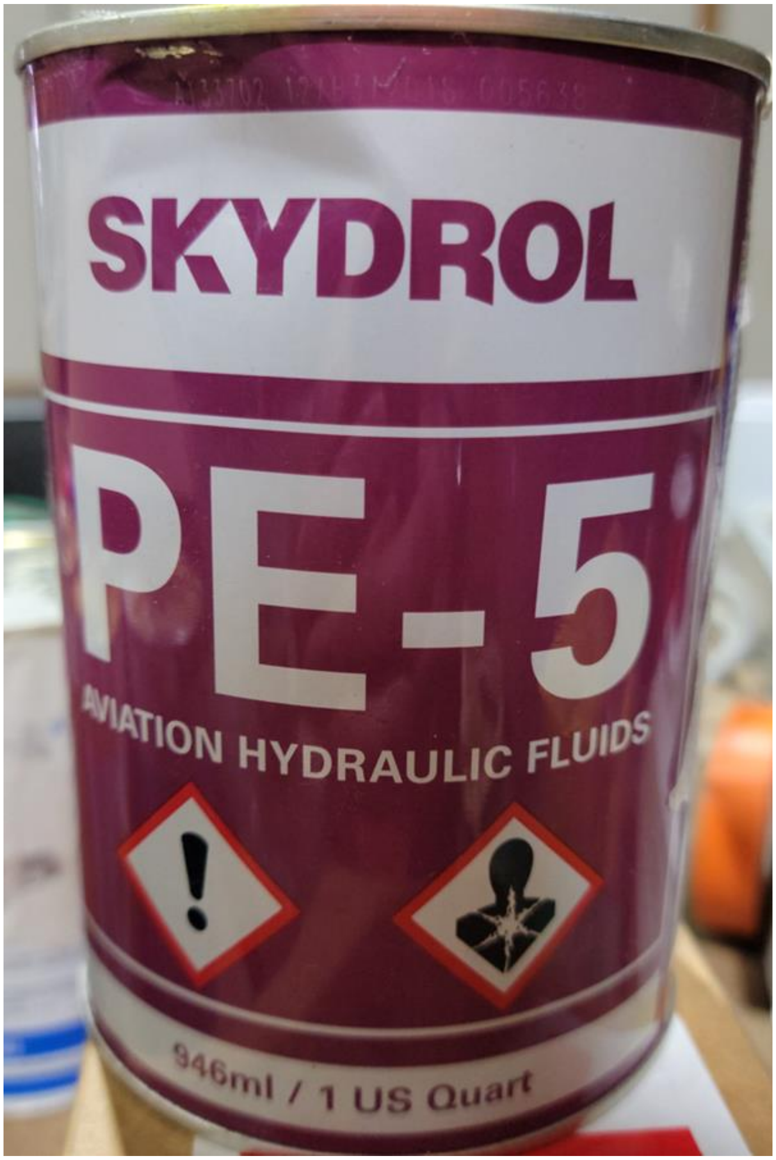


Figure A- 5. Eastman Skydrol® PE-5 Hydraulic Fluid

Eastman Skydrol PE-5 specifications are available at:

https://productcatalog.eastman.com/tds/ProdDatasheet.aspx?product=71093410&pn=Skydrol+PE-5#_ga=2.137703216.1006924206.1659910654-363650023.1659910654

Figure A- 6. Safewing Type 1 Deicing Fluid

Safewing LDF 88 Dilute Type 1 Aircraft Deicing Fluid specifications are available at:

https://aircraftdeicinginc.com/

B Engine test logs

Table B- 1. May 16, 2022 Engine Test Log

Time	**Engine**	**Bleed**	**Heater**	**Contaminant**	**Rate**	**Contaminant Concentration**	**Cooling**	**Manometer**	**Engine Inlet Air Flow**	**Notes**
	(on/off)	Temp	(on/off)		ml/hr	ppmW		in H2O	kg/s	
13:00	on	off	off	none	-	0	max			approximate time working on dyno
14:12	on	200C	off	none		0	max			flush bleed air lines stabilize
14:47	on	200C	off	none		0	max			Baseline
15:00						0		0.24	0.838	
15:56	on	200C	off	2389	15 ml/hr		max			stabilize
16:00								0.29	0.921	
16:45	on	200C	off	2389	15 ml/hr		max			sample
17:00								0.3	0.936	
17:50								0.55	1.268	
17:55	on	200C	off	none			max			refill injection syringe
17:58	on	200C	off	2389	15 ml/hr		max			
18:10	on	260C	off	2389	23 ml/hr		max			stabilize
18:13								0.55	1.268	
18:44	on	260C	off	2389	23 ml/hr		max			sample
19:50	on	260C	off	none			max			return to baseline
20:14	on	260C	off	none			reduced			
20:34	on	260C	off	none			max			
20:45	off									time approximate

Table B- 2. May 17, 2022 Engine Test Log

Time	**Engine**	**Bleed**	**Heater**	**Contaminant**	**Rate**	**Cooling**	**Manometer**	**Flow**	**Notes**
	(on/off)	Temp	(on/off)				in H2O	kg/s	
7:19	on	off	off	none		max			
7:33	on	200C	off	none		reduced			bleed disconnected from manifold
7:50	on	200C	off	none		reduced			119F downstream of HX
8:02	on	200C	off	none		reduced			133F
8:10	on	200C	off	none		reduced			140F
8:14	on	200C	off	none		reduced			100F
8:15	on	200C	off	none		max			Connect bleed manifold
8:40	on	200C	off	none		max			Baseline Start
8:43	on	200C	off	none		max	0.32	0.967	
9:33	on	200C	off	none		max	0.315	0.959	
9:45	on	200C	off	Jet II	17 ml/hr	max			Stabilize
10:11	on	200C	off	Jet 2	17 ml/hr	max	0.31	0.951	Sample
11:13	on	to max	off	Jet 2	17 ml/hr	max			
11:14	on	to max	off	none		max			filling syringe
10:16	on	to max	off	Jet 2	17 ml/hr	max			
10:25	on	to max	off	Jet II	17 ml/hr	max	0.52	1.232	
11:23	on	250C	off	Jet 2	17 ml/hr	max			at max, stabilizing
11:24	on	250C	off	Jet 2	22ml/hr	max			~11:10-11:35 fuel truck filling tank
11:52	on	250C	off	Jet 2	22 ml/hr	max			sampling
12:23	on	250C	off	Jet II	22 ml/hr	max	0.53	1.244	
12:36	on	250C	off	Jet II	22 ml/hr	max			Pegasor Valves Opened both engine units, closed today until now
12:45	on	250C	off	Jet II	22 ml/hr	max			Outside Air Fan Off until now
13:02	on	250C	off	None		max			Return to Baseline

Time	**Engine**	**Bleed**	**Heater**	**Contaminant**	**Rate**	**Cooling**	**Manometer**	**Flow**	**Notes**
	(on/off)	Temp	(on/off)				in H2O	kg/s	
13:38	on	250C	off	None		reduced			tried to maintain 140F on Heat Ex exit
14:29	on	200C	off	None		max			start reducing bleed temperature
14:35	on	200C	off	None		max			conditions achieved, stabilize
15:14	on	200C	off	None		max			Baseline Start
16:05	on		off	None		max	0.27	0.879	
16:16	on	200C	off	387	16 ml/hr	max			
16:42	on	200C	off	387	16 ml/hr	max			Sampling start
16:44	on		off	387	16 ml/hr	max	0.28	0.896	
17:45	on	250C	off	387	16 ml/hr	max			Start increase
17:53	on	250C	off	387	16 ml/hr	max			On condition
17:55	on	250C	off	none		Max			Syringe refill
17:57	on	250C	off	387	16 ml/hr				
17:58	on						0.49	1.19	
18:00	on	250C	off	387	22 ml/hr				stabilizing
18:05	on						0.5	1.2	
18:17	on	250C	off	387	22 ml/hr				Sampling
18:45	on						0.5	1.21	
19:20	on	250C		None		reduced			clean out
19:53	on			None		max			start shut down
19:57	on	off		None					
19:59									shut down complete

Table B- 3. May 18, 2022 Engine Test Log

Time	**Engine**	**Bleed**	**Heater**	**Contaminant**	**Rate**	**Cooling**	**Manometer**	**Flow**	**Notes**
	(on/off)	Temp	(on/off)				in H2O	kg/s	
7:28	on	off	off	none		max			engine start
7:37	On	on	off	none		max			
7:43	on	200C		none		reducing			
8:02		200C		none					140
8:05		200C		none		max			
8:14	on	200C	off	none		max			Baseline Start
8:18							0.34	1.018	
8:48							0.33	1.000	
9:21	on	200C	off	PE-5	18 ml/hr	max			start stabilizing
9:29							0.33	0.996	
9:51	on	200C	off	PE-5	18 ml/hr				start sampling
10:03							0.34	1.007	
							0.33	0.992	
10:53									Refill Syringe
10:56		increase							
11:06		250C	off	PE5	18 ml/hr	max			Start Stabilize
11:38							0.59	1.327	
11:38	on	250C	off	PE-5	24 ml/hr	max			Sampling Start
12:30							0.595	1.328	
12:43	on	250C	off	none		max			return to baseline
12:44	on	decreasing	off	none		max			return to baseline
12:56	on	200C	off	none		max			baseline
12:58							0.305	0.951	
13:26	on	200C	off	none		reduce			start cleaning out
13:35	on	200C	off	none		reduce			at 145
14:03	on	200C	off	none		max			
14:23	on	200C	off	none		max			start baseline sample
14:28							0.31	0.957	
15:08							0.3	0.939	
15:34	on	200C	off	HyJet IVA	17 ml/hr	max			started but hose came off
15:37	on	200C	off	HyJet IVA	17 ml/hr	max			start injection
15:56							0.305	0.944	
16:00	on	200C	off	HyJet IVA	17 ml/hr	max			Fuel Truck Arrive
16:17	on	200C	off	HyJet IVA	17 ml/hr	max			Fuel Truck Gone

Time	Engine	Bleed	Heater	Contaminant	Rate	Cooling	Manometer	Flow	Notes
	(on/off)	Temp	(on/off)				in H2O	kg/s	
16:19	on	200C	off	HyJet IVA	17 ml/hr	max			Start Sampling
16:42							0.3	0.934	
17:24	on	200c	off	none		max			Refill Syringe
17:26	on	200C	off	HyJet IVA	17 ml/hr	max			Start Raising Bleed Temperature
17:28	on	250C	off	HyJet IVA	17 ml/hr	max			
17:32							0.52	1.235	
17:34	on	250C	off	HyJet IVA	22 ml/hr	max			Stabilizing
17:54	on	250C	off	HyJet IVA	22 ml/hr	max			Start Sampling
17:59							0.52	1.235	
18:25							0.52	1.235	
18:58	on	250C		none		decreasing			sampling complete
19:00		250C							at 140
19:53	on	250C		none		Max			
19:58	on	off							
20:02	off								

Table B- 4. May 19, 2022 Engine Test Log

Time	Engine	Bleed	Heater	Contaminant	Rate	Cooling	Mano	Flow	Notes
	(on/off)	Temp	(on/off)				in H2O	kg/s	
7:00	off	off	off	none		max			
7:14	on	off	off	none		max			
7:23	on	on	off	none		max			
7:28	on	200C	off	none		max			
7:47							0.33	0.994	
7:54	on	200C	off	none		max			Start Baseline
8:09							0.32	0.979	
8:44							0.33	0.989	
8:56	on	200C	off	Deice Type 1	18 ml/hr	max			Start Stabilizing
9:26							0.32	0.972	
9:28	on	200C	off	Deice Type 1	18 ml/hr	max			Start Sampling
9:55							0.32	0.974	
10:31	on	200C	off	none		max			Start Return to Baseline
10:36							0.32	0.968	

Time	Engine	Bleed	Heater	Contaminant	Rate	Cooling	Mano	Flow	Notes
11:08	on	200C	off	none		reduced			start cleaning out
11:20		200C	off	none		reduced			at 140
11:23									at 144 probably the peak
11:36							0.3	0.938	
11:49	on	200C	off	none		max			
12:14	on	200C	off	none		max			Start Baseline Sampling
12:18							0.31	0.951	
12:57							0.3	0.936	
13:17	on	200C	off	Jet II	17 ml/hr	max			Start Stabilizing
13:31							0.3	0.936	
13:52	on	200C	off	Jet II	17 ml/hr	max			Start Sampling
13:58							0.3	0.934	
14:24							0.28	0.906	
14:55	on	200C	off	none		max			refilling syringe
14:57	on	increasing	off	Jet II	17 ml/hr	Max			22
							0.52	1.234	
15:05	on	250C	off	Jet II	22 ml/hr	max			at conditions 259C
15:20							0.515	1.222	
15:40	on	250C	off	Jet II	22 ml/hr	max			Start Sampling
15:45							0.505	1.21	
16:08							0.5	1.204	
16:13	on	250C	off	none		max			return to baseline
16:57	on	250C	off	none		reduced			start clean-out
17:02									peaked at 147
17:09									Leveled at ~ 141
17:43	on	250C	off	none		max			
17:53	on	off	off	none		max			start shut down

Table B- 5. May 20, 2022 Engine Test Log

Time	**Engine**	**Bleed**	**Heater**	**Contaminant**	**Rate**	**Cooling**	**Mano**	**Flow**	**Notes**
	(on/off)	Temp	(on/off)				in H2O	kg/s	
8:03	on	off	off	none		max			Engine Start
8:05	on	on							approximate time
8:10	on	200C	off	none		max			start stabilizing
8:33	on	200C	off	none		max			start baseline
8:48							0.335	1.019	
9:10							0.34	1.026	
9:16	on	200C	off	Jet II	3.7 ml/hr	max			Start 1ppm
9:32							0.345	1.034	
9:52	on	200C	off	Jet II	7.4 ml/hr	max			start 2 ppm
9:56							0.345	1.034	
10:13							0.35	1.041	
10:29	on	200C	off	Jet II	11.2 ml/hr	max			Start 3 ppm
10:33							0.355	1.048	
11:03							0.355	1.047	
11:06	on	200C	off	Jet II	18.8 ml/hr	max			Fuel truck about this time
11:37							0.345	1.03	
11:41	on	200C	off	Jet II	37.1 ml/hr	max			
12:03							0.34	1.022	
12:44	on	200C	off	none					Start return to baseline
12:49							0.34	1.02	
13:55							0.33	1.003	
14:42	on	200C	off	none		reducing			start reducing fan, 81 at start, aiming for 100
14:46							0.32	0.988	
15:02		200C	off	none		reduced			leveled at 102
15:04		200C	off	none		reduced			start increasing aiming for 120
15:16		200C	off	none		reduced			122
15:19		200C	off	none		reduced			leveling at 123
15:25		200C	off	none		reduced			increasing aiming for 140
15:30		200C	off	none		reduced			140
15:34		200C	off	none		reduced			level at 142
15:45		200C	off	none		reduced			152, no change on controls air

Time	**Engine**	**Bleed**	**Heater**	**Contaminant**	**Rate**	**Cooling**	**Mano**	**Flow**	**Notes**
	(on/off)	Temp	(on/off)				in H2O	kg/s	
									temp warmed dramatically
15:52		200C	off	none		reduced			~level at 156
15:58		250C	off	none		reduced			increase power
16:32		250C	off	none		reduced			got up to 161
16:36		250c	off	none		max			start decrease in power
16:47		200C	off	none		Max			been at 200C for a bit
16:50		200C	off	none		Max			start getting forklift in place for exhaust test.
17:23		200C	off	none		Max			end forklift exhaust
17:28		200C	off	none		Max			Pickup Exhaust Start Silverado
17:51		200C	off	none		Max			end pickup test Silverado
17:54		200C	off	none		Max			Start Pickup Test Tacoma
18:06	on	200C	off	none		Max			end pickup test Tacoma
18:21		off	off	none		Max			start shut down
18:24	off								

Table B- 6. May 23, 2022 Engine Test Log

Time	**Engine**	**Bleed**	**Heater**	**Contaminant**	**Rate**	**Cooling**	**Manometer**	**Flow**	**Notes**
	(on/off)	Temp	(on/off)				in H2O	kg/s	
10:30	off	off	off	none		max			
10:52	on	off	off	none		max			Engine Start
10:55	on	on	off	none		max			Bleed Air On
11:03	on	200C	off	none		max			Start Baseline
							0.36	1.056	
11:34	on	200C	off	none		max			Connect Exhaust, anti-seize on pipe burning off
12:04	on	200C	off	turbine ex		max			Start increasing bleed air temp
12:10	on	250C	off	turbine ex		max	0.585	1.346	at 248
13:18	on	250C	off	turbine ex		reducing	0.58	1.342	start cleaning out, with

Time	**Engine**	**Bleed**	**Heater**	**Contaminant**	**Rate**	**Cooling**	**Manometer**	**Flow**	**Notes**
	(on/off)	Temp	(on/off)				in H2O	kg/s	
									exhaust ingestion
13:26	on	250C	off	turbine ex		reduced			at 141 leveling
13:10							0.59	1.349	
14:19	on	250C	off	none		reduced			Exhaust disconnected
14:51	on	250C	off	none		max			
15:02	on	off	off	none		max			start engine shut down
15:05	off	off	off	none		max			

C Instrument descriptions

Table C- 1. Instrument description list

Engine Inlet - Active Sampling Instruments	**Model**	**Instrument Serial Number**
Naneos Partector 2 Ultra Fine Particle Sensor-Yellow Pelican Case	152	8181
Pegasor AQ Indoor	Pegasor Loaner PIAQ-60	0137
PP Systems WMA-5 Carbon Dioxide Analyzer	KSU ACER Lab WMA-5	WMA0105
Teledyne Gas Filter Correlation CO Analyzer	Honeywell Loaner 300E	692
Honeywell ppbRAE 3000-Boeing #3	Boeing Loaner	594-908441
Honeywell ppbRAE 3000-Honeywell	Honeywell Loaner	594-904717 (594-905178 physically on unit)
TSI Condensation Particle Counter	TSI 3007	3007-01180007
Engine Inlet -Diffusion Type Instruments to be placed in Enclosure	Large Green Box	
Piera Systems	KSU NGML IPS7100	211000177
First Alert Smoke Detector	FAA ACER modified Model No. 3120B	Unit 1
Digital Manometer	Aircraft Env Solutions Loaner	202145230
Engine Bleed -Diffusion Type Instruments to be placed in Enclosure		
Astronics Metal Oxide Sensor	Astronics Loaner	S001
Astronics Metal Oxide Sensor	Astronics Loaner	S002
Astronics Metal Oxide Sensor	Astronics Loaner	S003
Sensirion Electrochemical Formaldehyde (HCHO) Sensor	Aircraft Env Solutions Loaner SFA30	SFA3x3B4D
Sensirion Electrochemical Formaldehyde Sensor	Aircraft Env Solutions Loaner SFA30	SFA3x3B30
Sensirion Electrochemical Formaldehyde Sensor	Aircraft Env Solutions Loaner SFA30	SFA3x3B3A
First Alert Smoke Detector	FAA ACER modified Model No. 3120B	Unit 3
Teledyne ACES Cabin Air Sensor	Teledyne Controls Loaner	AD00024
Teledyne ACES Cabin Air Sensor	Teledyne Controls Loaner	AD00026
Naneos Partector 2 Ultra Fine Particle Sensor	Naneos Loaner Model 150	8147
Naneos Partector 2 Ultra Fine Particle Sensor	Naneos Loaner Model 150	8284
TSI QTRAK XP IAQ Monitor-PM Sensor	TSI Loaner Model 7850	14302049017

Engine Inlet - Active Sampling Instruments	**Model**	**Instrument Serial Number**
TSI QTRAK XP IAQ Monitor-Base	TSI Loaner Model 7850	76802049015
TSI QTRAK XP IAQ Monitor-CO2 Sensor	TSI Loaner Model 801399	13992102021
TSI QTRAK XP IAQ Monitor-CO Sensor	TSI Loaner Model 801401	14012112002
TSI QTRAK XP IAQ Monitor-NO Sensor	TSI Loaner Model 801404	14042041002
TSI QTRAK XP IAQ Monitor-O3 Sensor	TSI Loaner Model 801406	14062041001
TSI QTRAK XP IAQ Monitor-TVOC L Sensor	TSI Loaner Model 801408	14082051005
TSI QTRAK XP IAQ Monitor-CH20 Sensor	TSI Loaner Model 801409	14092203002
Interscan Formaldehyde Analyzer	Interscan Loaner Model 8160-2000b	926394
AMETEK Mocon II	KSU NGML Model 043-737	0422GM1147
Piera Systems Canaree	KSU NGML Owned	CNR-15-22D000043
Digital Manometer	Aircraft Env. Solutions Loaner	202145246
Bleed Air Sampling Equipment- Upstream of Bleed Air Precooler		
Pegasor PPS-M High Temperature Particle Counter (higher temp)	Pegasor Loaner Model PPS-M	S/N 5129
Bleed Air Sampling Equipment- Downstream of Bleed Air Precooler		
PP Systems Carbon Dioxide Analyzer	KSU ACER Lab Model WMA-5	WMA0152
Airsense Aerotracer	Airsense Loaner AT 39	39015
Airsense AQM	Airsense Loaner	N/A
Teledyne Gas Filter Correlation CO Analyzer 300E	Honeywell Loaner 300E	693
TSI Aerosol Particle Sizer	KSU NGML Model 332100	70742031
TSI Aerosol Particle Sizer	KSU NGML Model 332100	70626096
TSI Electrostatic Classifier	KSU NGML Model 308000	71244008
TSI Condensation Particle Counter	KSU NGML Model 377500	3775124502
TSI Nanoscan SMPS	Boeing Loaner Model 391000	3910181304
TSI Optical Particle Sizer	Boeing Loaner Model 3330	3330181003
Pegasor PPS-M High Temperature Particle Counter (lower temp)	PPS-M	5107
Picarro G2307 CRDS Formaldehyde Analyzer	Picarro Loaner Model G2307	3462-LBDS2003
Picarro G2401 CRDS CO, CO2, CH4, H2O	Picarro Loaner Model G2401	
Honeywell ppbRAE 3000-Boeing #1	Boeing Loaner	594-908463
Honeywell ppbRAE 3000-Boeing #2	Boeing Loaner	594-908467
Honeywell ppbRAE 3000-Boeing #4	Boeing Loaner	594-908228

Engine Inlet - Active Sampling Instruments	**Model**	**Instrument Serial Number**
Pall CAQS	Pall Loaner	Labeled "CAQS 2"
Pall CAQS	Pall Loaner	Labeled "CAQS 3"
Pall CAQS	Pall Loaner	Labeled "CAQS 4"
Pegasor AQIndoor	PIAQ-60	0137
KSU Laboratory Sampling Equipment		
SKC Legacy Pump 1	Boeing Loaner100-3002	1332
SKC Legacy Pump 2	Boeing Loaner100-3002	1730
SKC Legacy Pump 3	Boeing Loaner100-3002	1743
Alicat Mass Flow Controller 1	Honeywell Loaner MC-2SLPM-D-24V/5M, RIN, DS, Gas: Air	17668
Alicat Mass Flow Controller 2	Honeywell Loaner MC-2SLPM-D-24V/5M, RIN, DS, Gas: Air	16790
Alicat Mass Flow Controller 3	Honeywell Loaner MC-2SLPM-D-24V/5M, RIN, DS, Gas: Air	16789
Alicat Mass Flow Controller 4	Honeywell Loaner MC-2SLPM-D-24V/5M, RIN, DS, Gas: Air	17665
Alicat Mass Flow Controller 5	Honeywell Loaner MC-2SLPM-D-24V/5M, RIN, DS, Gas: Air	17129
Alicat Mass Flow Controller 6	Honeywell Loaner MC-2SLPM-D-5M, 5IN, Gas: N2, STP: 0 ℃, HC	113095
TSI Digital Flowmeter	KSU NGML 4043H	3123 1007
Air Dimensions Dia-Vac Pump	M102-BT-AA1	1406492
Tisch Environmental High-Volume Sampler #1	Boeing Loaner	2572
Tisch Environmental High-Volume Sampler #2	Boeing Loaner	2578

D Master parts list

- Allison 250 C28B Engine
- Antrader Forged Brass Ball Valve Y Shaped Shut Off Switch, 3/8" x 3/8" x 3/8" Barb Tee Pipe Tubing Fitting Coupler, with 2 Operation Switches
- Copper Tubing- Refrigeration Grade
- General Electric Model 1G35 Inductor Dynamometer Serial No. 6842177
- Digital Handheld Manometer, URPRO HVAC Air Vacuum/Gas Differential Pressure Gauge Meter Tester ±13.78kPa ±2PSI, 11 Units w/Backlight, 1-2 Pipes Ventilation Air Condition System Measurement
- Dyne Systems Model OECPAU015RS-GC Control Module Serial No. SN2599
- Dyne Systems Model OIL5-OCS-04 Control Module Serial No. SN2602
- Butanol- high purity used for SMPS Condensation Particle Counter
- Isopropyl Alcohol- high purity, used for NanoScan and TSI3007 Condensation Particle Counters
- Fasco Vane Pump, Model No. 1532-P104-G597X, 115 V, 60 Hz
- Menards Masterforce® 21" Suitcase Toolbox, Model number: 1533.3
- Minimprover 4PCS 1/4" ID Hose Barb Thru-Bulkhead Hex Union Brass Straight Fitting with Flat Washer Gasket Water/Fuel/Air
- Minimprover 4PCS 5/16" ID Hose Barb Thru-Bulkhead Hex Union Brass Straight Fitting with Flat Washer Gasket Water/Fuel/Air
- Minimprover 8PCS 3/8" ID Hose Barb Thru-Bulkhead Hex Union Brass Straight Fitting with Flat Washer Gasket Water/Fuel/Air
- Minimprover 8PCS 1/2" ID Hose Barb Thru-Bulkhead Hex Union Brass Straight Fitting with Flat Washer Gasket Water/Fuel/Air
- RIDGID 32975 Model 103 Close Quarters Tubing Cutter, 1/8-inch to 5/8-inch Tube Cutter , Silver , Small

- New Era Pump Systems Model No. 300 Syringe Pump
- HSW 50(60) Syringe
- Pelican 1300 Protector Case- For Ambient Diffusion Samplers
- Sargent Art Plastilina Modeling Clay, 2-Pound, White (Packaging may vary)- sealing instrument cases.
- SKC Tedlar® Sample Bag, Catalog Number 231-03, 3-Liter
- Sioux Chief 672XV0490, 1/2" PEX Manifold w/valves, 3/4" PEX in, closed
- Tisch Model TE-5007 Environmental PUF Sample Train in Aluminum Housing (SN 2572, S/N 2578)
- TSI Model 4030 Flowmeter
- TSI 3001788 -- $590 -- 0.19" ID Conductive Tubing (fits 1/4" barb) 50' Roll
- TSI 3001789 -- $620 -- 0.31" ID Conductive Tubing (fits 3/8" barb) 50' Roll
- TSI 3001835 -- $800 -- 0.44" ID Conductive Tubing (fits 1/2" barb) 25' Roll
- TSI 3001901 -- $620 -- 0.687" Conductive Tubing (fits 3/4" barb) 25' Roll
- TSI Scanning mobility particle sizer: (3936L75-M classifier, 3087 X-ray neutralizer, 3081 differential mobility analyzer, 3775 condensation particle counter)
- Calibrated Vacuum Gauge (0-30" Hg) with 30-minute flow restrictor– Provided by AAC Laboratory for control and verification of Summa Canister Fill
- Calibrated Vacuum Gauge (0-30" Hg) with 60-minute flow restrictor– Provided by AAC Laboratory for control and verification of Summa Canister Fill.
- Summa Canister (6-Liter), Cleaned and Evacuated
- Waters Sep-Pak DNPH-silica cartridges, Part number WAT037500
- Waters SEP-Pak Ozone Scrubber Potassium Iodide, Plus short cartridge, part number WAT054420
- Test Leads Set with Alligator Clips 39 Inches Double-ended Jumper
- TE-QMA4,4-inch Diameter QMA Filters for PUF, 100/box

E Lab chemical sample logs

Table E- 1. May 16, 2022 Lab Chemical Sample Log

Date	5/16/2022	5/16/2022	5/16/2022	5/16/2022	5/16/2022	5/16/2022	5/16/2022	5/16/2022
Time	14:12	14:12	14:47	14:47	16:45	16:45	18:44	18:44
TO-11 DNPH Client Sample ID	1-Shipping Blank	8-Field Blank	32.2L Baseline 200 C Inlet	31.2L Baseline 200 C Bleed	4-32.0L Eastman 2389 200 C Inlet	5-31.2L Eastman 2389 200 C- Bleed	6-34.6L Eastman 2389 260 C Inlet	7-33.8L Eastman 2389 260 C Bleed
TO-11 DNPH AAC Report/Sample ID	221141-31784	221141-31783	221141-31785*	221141-31786*	221141-31787	221141-31788	221141-31789	221141-31790
EPA 8270E Quartz Filter Client Sample ID		8-Field Blank	2-Baseline 200 C Inlet	3-Baseline 200 C Bleed	4-Eastman 2389 200 C Inlet	5-Eastman 2389 200 C Bleed	6-Eastman 2389 260 C Inlet	7-Eastman 2389 260 C Bleed
EPA 8270E Quartz Filter RJLee Report/ Sample ID		W205178-07A	W205178-01A	W205178-02A	W205178-03A	W205178-04A	W205178-05A	W205178-06A
EPA TO-15 Summa Client Sample ID			1-Baseline 200 C Inlet	2-Baseline 200 C Bleed	3-Eastman 2389 200 C Inlet	3-Eastman 2389 200 C Bleed	5-Eastman 2389 260 C Inlet	6-Eastman 2389 260 C Bleed
EPA TO-15 Summa AAC Report / Sample ID			221095-31439	221095-31440	221095-31441	221095-31442	221095-31443	221095-31444
EPA TO-17 Tenax Cartridge #/ Client Sample ID	463641/ Shipping Blank	463638/ Field Blank	A035217/ Baseline 200 C Inlet	A035205/ Baseline 200 C Bleed	463636/ Eastman 2389 200 C Inlet	463637/ Eastman 2389 200 C Bleed	A035254/ Eastman 2389 260 C Inlet	463647/ Eastman 2389 260 C Bleed
EPA TO-17 Tenax RJ Lee Report/ Sample ID	W205179-39	W205179-25	W205179-42	W205179-43	W205179-45	W205179-41	W205179-44	W205179-40
Bleed Temp	200C	200C	200C	200C	200C	200C	260C	260C
Contaminant	none	none	none	none	Eastman 2389	Eastman 2390	Eastman 2391	Eastman 2392
Rate	0	0	0	0	15	15	23	23
ppmW	0	0	0	0	5	5	5	5

Table E- 2. May 17, 2022 Lab Chemical Sample Log

Date	5/17/2022	5/17/2022	5/17/2022	5/17/2022	5/17/2022	5/17/2022	5/17/2022
Time	7:33	8:40	8:40	10:11	10:11	11:52	11:52
TO-11 DNPH Client Sample ID		9-30.4L Baseline 200 C Inlet	10-32.4 Baseline 200 C Bleed	11-32.6L MJO II 200 C Inlet	12-32.2L MJO II 200 C Bleed	13-31.6L MJO II 250C Inlet	14-31.8L MJOl II 250C Bleed
TO-11 DNPH AAC report/Sample ID		221141-31794	221141-31795	221141-31796	221141-31797	221141-31798	221141-31799
TO-13 PUF/XAD Client Sample ID	9-Field Blank	11 Baseline 200 C Inlet	12-Baseline Bleed		13 MJO II 200 C Bleed		14 MJOl II 250C Bleed
TO-13 PUF/XAD RJLee Report/ Sample ID	W205131-07A	W205131-08A	W205131-09A		W205131-10A		W205131-11A
EPA 8270E Quartz Filter Client Sample ID		10-Baseline MJII Inlet	11-Baseline MJII Bleed		13 MJO II 200 C Bleed		15-MJO II 250 C Bleed
EPA 8270E Quartz Filter RJLee Report/ Sample ID		W205178-08A	W205178-09A		W205178-10A		W205178-11A
EPA TO-15 Summa Client Sample ID		7-Baseline Condition-Inlet	8-Baseline Condition-Bleed	9-Mobil Jet II 200C Inlet	10-MJO II 200C Bleed	11 MJO II 250C Inlet	12 MJO II 250C Bleed
EPA TO-15 Summa AAC Report / Sample ID		221095-31445	221095-31446	221095-31447	221095-31448	221095-31449	221095-31450
EPA TO-17 Tenax Cartridge #/ Client Sample ID		463634/ Baseline 200 C Inlet	463631/ Baseline 200 C Bleed		463643/ MJO II 200 C Bleed	463624/ MJO II 250C Inlet	463623/ MJOl II 250C Bleed
EPA TO-17 Tenax RJ Lee Report/ Sample ID		W205179-36	W205179-38		W205179-29	W205179-26	W205179-28
Bleed Temp	200C	200C	200C	200C	200C	250C	250C
Contaminant	none	none	none	Mobil Jet Oil II	Mobil Jet Oil II	Mobil Jet Oil II	Mobil Jet Oil II
Rate	0	0	0	17	17	22	22
ppmW	0	0	0	5	5	5	5
Manometer in. H2O				0.31			
Engine Inlet Air Flow kg/s				0.951			

Date	5/17/2022	5/17/2022	5/17/2022	5/17/2022	5/17/2022	5/17/2022	5/17/2022
Time	15:14	15:14	17:45	17:45	18:17	18:17	19:59
TO-11 DNPH Client Sample ID	15-33.2L MJO 387 Baseline 200C Inlet	16-32.2L MJO 387 Baseline 200C Bleed	17-29.6L MJO 387 200C Inlet	18-30.6L MJO 387 200C Bleed	19-30.2L MJO387 250C Inlet	20-30.6L MJO387 250C Bleed	21-Field Blank
TO-11 DNPH AAC report/Sample ID	221141-31800	221141-31801	221141-31802	221141-31803	221141-31804	221141-31805	221141-31791
TO-13 PUF/XAD Client Sample ID	15-Baseline 200C Inlet	16-Baseline 200C Bleed		18 MJO 387 200C Bleed		19 MJO387 250 C Bleed	
TO-13 PUF/XAD RJLee Report/ Sample ID	W205177-01A	W205177-02A		W205177-03A		W205177-04A	
EPA 8270E Quartz Filter Client Sample ID	16-Baseline 200 C Inlet	17-Baseline 200C Bleed	17a MJO387 200C inlet	18-Mobil Jet Oil 387 200C Bleed	19-MJO387 Inlet Max C	20-MJO 387250 C Bleed	21-Field Blank
EPA 8270E Quartz Filter RJLee Report/ Sample ID	W205178-12A	W205178-13A	W205178-14A	W205178-15A	W205178-16A	W205178-17A	W205178-18A
EPA TO-15 Summa Client Sample ID	13 MJO387 Baseline 200C Inlet	14-MJO387 Baseline 200C Bleed	15 MJO387 200 °C Inlet	16 MJO387 200 °C Bleed	17-MJO 387 250 °C Inlet	18 MJO387 250°C Bleed	
EPA TO-15 Summa AAC Report / Sample ID	221106-31582	221106-31583	221106-31584	221106-31585	221106-31586	221106-31587	
EPA TO-17 Tenax Cartridge #/ Client Sample ID	463648/ Baseline 200 C Inlet	463639/ Baseline 200 C Bleed	463626/ MJO 387 200C Inlet	463633/ MJO 387 200C Bleed	463625/ MJO387 250C Inlet	463646/ MJO 387 250C Bleed	463622/ Field Blank
EPA TO-17 Tenax RJ Lee Report/ Sample ID	W205179-30	W205179-27	W205179-31	W205179-33	W205179-34	W205179-32	W205179-37
Bleed Temp	200C	200C	250C	250C	250C	250C	250C
Contaminant	None	None	Mobil Jet Oil 387	Mobil Jet Oil 388	Mobil Jet Oil 387	Mobil Jet Oil 387	Mobil Jet Oil 387
Rate	0	0	16	16	22	22	0
ppmW	0	0	5	5	5	5	0

Table E- 3. May 18, 2022 Lab Chemical Sample Log

Date	5/18/2022	5/18/2022	5/18/2022	5/18/2022	5/18/2022	5/18/2022	5/18/2022
Time	8:14	8:14	9:51	9:51	11:38	11:38	12:56
TO-11 DNPH Client Sample ID	22-30.0L PE-5 Baseline 200C Inlet	23-29.6L PE-5 Baseline 200C Bleed	24-30.2L PE-5 200°C Inlet	25-30.0L PE-5 200C Bleed	26-30.4L PE-5 250°C Inlet	27-30.4L PE-5 250°C Bleed	28-31.0L HyJet IV-A Baseline 200 C Inlet
TO-11 DNPH AAC Report/Sample ID	221141-31806	221141-31807	221141-31808	221141-31809	221141-31810	221141-31811	221141-31812
TO-13 PUF/XAD Client Sample ID	23-PE-5 Baseline 200C Inlet	24-PE-5 Baseline200°C Bleed				26-PE-5 250C Bleed	
TO-13 PUF/XAD RJLee Report/ Sample ID	W205177-05A	W205177-06A				W205177-07A	
EPA 8270E Quartz Filter Client Sample ID	1a PE-5 Baseline 200C Inlet	1b-PE-5 Baseline 200C Bleed	26-PE-5 Inlet 200C	27-PE-5 Bleed 200C	28-PE-5 250 C Inlet	29-PE-5 250C Bleed	31-Baseline HyJet IV-A+ Inlet
EPA 8270E Quartz Filter RJLee Report/ Sample ID	W205178-19A	W205178-20A	W205178-21A	W205178-22A	W205178-23A	W205178-24A	W205178-26A
EPA TO-15 Summa Client Sample ID	19-Baseline Condition Inlet	20-Baseline Condition Bleed	21-PE-5 200°C Inlet	22-PE-5 200°C Bleed	23-PE-5 250 °C Inlet	24-PE-5 250 °C Bleed	25-Baseline HyJet IV-A 200C Inlet
EPA TO-15 Summa AAC Report / Sample ID	221106-31588	221106-31589	221106-31590	221106-31591	221106-31592	221106-31593	221134-31730
EPA TO-17 Tenax Cartridge #/ Client Sample ID	463642/ PE-5 Baseline 200C Inlet	463635/ PE-5 Baseline 200C Bleed	A035183/ PE-5 200C Inlet	463644/ PE-5 200 C Bleed	463650/ PE-5 250C Inlet	A034773/ PE-5 250C Bleed	A035167/ HyJet IV-A Baseline 200 C Inlet
EPA TO-17 Tenax RJ Lee Report/ Sample ID	W205179-24	W205179-35	W205179-23	W205179-20	W205179-21	W205179-22	W205179-18
Bleed Temp	200C	200C	200C	200C	200C	200C	200C
Contaminant	none	none	Skydrol PE-5	Skydrol PE-5	Skydrol PE-5	Skydrol PE-5	none
Rate	0	0	18	18	24	24	0
ppmW	0	0	5	5	5	5	0

Date	5/18/2022	5/18/2022	5/18/2022	5/18/2022	5/18/2022	5/18/2022	5/18/2022
Time	12:56	16:19	16:19	17:54	17:54	17:54	17:54
TO-11 DNPH Client Sample ID	29-30.8L HyJet IV-A Baseline 200C Bleed	30-30.4L HyJet IV-A 200 C Inlet	31-30.2L HyJet IV-A 200 C Bleed	32-30.4L HyJet IV-A 250 C Inlet	33-30.4L HyJet IV-A 250C Bleed	34-Field Blank	
TO-11 DNPH AAC Report/Sample ID	221141-31813	221141-31814	221141-31815	221141-31816	221141-31817	221141-31792	
TO-13 PUF/XAD Client Sample ID					30-HyJet IV-A+ 250C Bleed	21-Field Blank	
TO-13 PUF/XAD RJLee Report/ Sample ID					W205177-08A	W205177-09A	
EPA 8270E Quartz Filter Client Sample ID	32-Baseline HyJet IV-A+ Bleed	33 HyJet IV-A+ 200 C Inlet	34 HyJet IV-A+ 200 C Bleed	35 HyJet IV-A+ Inlet 250C Inlet	36 HyJet IV-A+ 250C Bleed	30-Field Blank	
EPA 8270E Quartz Filter RJLee Report/ Sample ID	W205178-27A	W205178-28A	W205178-29A	W205178-30A	W205178-31A	W205178-25A	
EPA TO-15 Summa Client Sample ID	26-Baseline HyJet IV-A 200C Bleed	27-Hyjet IV-A 200 C Inlet	28-Hyjet IV-A 200 C Bleed	29-Hyjet IV-A 250 C Inlet	30-Hyjet IV-A 250 C Bleed		
EPA TO-15 Summa AAC Report / Sample ID	221134-31731	221134-31732	221134-31733	221134-31734	221134-31735		
EPA TO-17 Tenax Cartridge #/ Client Sample ID	A035270/ HyJet IV-A Baseline 200C Bleed	Y59084/ HyJet IV A+ 200 C Inlet	Y59070/ HyJet IV-A+ 200 C Bleed	673918/ HyJet IV-A 250C Inlet	673917/ HyJet IV-A 250C Bleed	673930/ Field Blank	673925/ Shipping Blank
EPA TO-17 Tenax RJ Lee Report/ Sample ID	W205179-19	W205179-17	W205179-16	W205179-03	W205179-04	W205179-02	W205179-01
Bleed Temp	200C	200C	200C	250C	250C		
Contaminant	none	HyJet IVA	HyJet IVA	HyJet IVA	HyJet IVA	none	none
Rate	0	17	17	22	22	0	0
ppmW	0	5	5	5	5	0	0

Table E- 4. May 19, 2022 Lab Chemical Sample Log

Date	5/19/2022	5/19/2022	5/19/2022	5/19/2022	5/19/2022	5/19/2022	5/19/2022
Time	7:14	7:54	7:54	9:28	9:28	12:14	12:14
TO-11 DNPH Client Sample ID	39-Field Blank	35-29.4L Kilfrost Type 1 Deicing Fluid Baseline 200 C Inlet	36-29.6L Kilfrost Type 1 Deicing Fluid Baseline 200 C Bleed	37-30.0L Kilfrost Type 1 Deicing Fluid 200C Inlet	38-XX-XL Kilfrost Type 1 Deicing Fluid 200 C Bleed		
TO-11 DNPH AAC Report/Sample ID	221141-31793	221141-31818	221141-31819	221141-31820	221141-31821		
TO-13 PUF/XAD Client Sample ID							
TO-13 PUF/XAD RJLee Report/ Sample ID							
EPA 8270E Quartz Filter Client Sample ID		38 Kilfrost Type 1 Deicing Fluid Baseline 200C Inlet	39 Kilfrost Type 1 Deicing Fluid Baseline 200C Bleed	40 Kilfrost Type 1 Deicing Fluid 200 C Inlet	41 Kilfrost Type 1 Deicing Fluid Bleed 200C	42-MJII Baseline Replicate Sample Inlet 200 C	43-Baseline MJII 200C Bleed Replicate Sample
EPA 8270E Quartz Filter RJLee Report/ Sample ID		W205178-38A	W205178-39A	W205178-40A	W205178-41A	W205178-42A	W205178-43A
EPA TO-15 Summa Client Sample ID		31-Kilfrost Type 1 Deicing Fluid Baseline 200 C Inlet	32-Kilfrost Type 1 Deicing Fluid Baseline 200C Bleed	33 Kilfrost Type 1 Deicing Fluid 200C Bleed			
EPA TO-15 Summa AAC Report / Sample ID		221134-31736	221134-31737	221134-31738			
EPA TO-17 Tenax Cartridge #/ Client Sample ID	673927/ Field Blank	673912/ Kilfrost Type 1 Deicing Fluid Baseline 200 C Inlet	673914/ Kilfrost Type 1 Deicing Fluid Baseline 200 C Bleed	673929/ Kilfrost Type 1 Deicing Fluid 200C Inlet	673923/ Kilfrost Type 1 Deicing Fluid 200C Bleed	673919/ MJII Baseline 200C Inlet Replicate Sample	673928/ Baseline MJII 200C Bleed Replicate Sample
EPA TO-17 Tenax RJ Lee Report/ Sample ID	W205179-09	W205179-05	W205179-06	W205179-07	W205179-08	W205179-10	W205179-11
Bleed Temp	off	200C	200C	200C	200C	200C	200C
Contaminant	none	none	none	Deice Type 1	Deice Type 1	none	none
Rate	0	0	0	18	18	0	0
ppmW	0	0	0	5	5	0	0
Manometer in. H2O							
Engine Inlet Air Flow kg/s							

Date	5/19/2022	5/19/2022	5/19/2022		5/19/2022	
Time	13:52	13:52	15:40		17:09	
TO-11 DNPH Client Sample ID		40-30.4L MJO II 200 C Bleed	41-30.4L MJO II 250 C Inlet Replicate Sample	42-30.2L MJOl II 250 C Bleed Replicate Sample		
TO-11 DNPH AAC Report/Sample ID		221141-31822	221141-31823	221141-31824		
TO-13 PUF/XAD Client Sample ID						
TO-13 PUF/XAD RJLee Report/ Sample ID						
EPA 8270E Quartz Filter Client Sample ID	44- MJII 200C Inlet Replicate Sample	45- MJO II 200C Bleed Replicate Sample	46 MJII 250 C Inlet Replicate Sample	47- MJII 250C Bleed Replicate Sample+	48-Cleanout MJII Inlet	49-Cleanout Bleed
EPA 8270E Quartz Filter RJLee Report/ Sample ID	W205178-44A	W205178-45A	W205178-46A	W205178-47A	W205178-48A	W205178-49A
EPA TO-15 Summa Client Sample ID		34 MJOII 200C Bleed Replicate Sample		35-MJO II 250C Bleed Replicate Sample		36-Clean Out Bleed
EPA TO-15 Summa AAC Report / Sample ID		221134-31739		221134-31740		221134-31741
EPA TO-17 Tenax Cartridge #/ Client Sample ID	673915/ MJII 200C Inlet Replicate Sample	673916/ MJO II 200C Bleed Replicate Sample	673922/ MJO II 250 C Inlet Replicate Sample	673926/ MJOl II 250 C Bleed Replicate Sample		
EPA TO-17 Tenax RJ Lee Report/ Sample ID	W205179-15	W205179-12	W205179-13	W205179-14		
Bleed Temp	200C	200C	250C	250C	250C	250C
Contaminant	Mobil Jet Oil II	Mobil Jet Oil II	Mobil Jet Oil II	Mobil Jet Oil II	Mobil Jet Oil II	Mobil Jet Oil II
Rate	17	17	22	22	0	0
ppmW	5	5	5	5	0	0

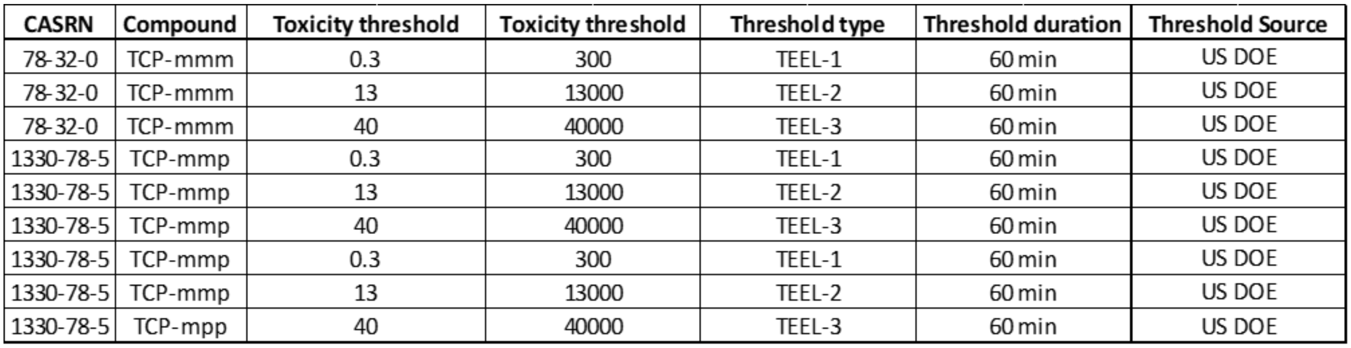
Table E- 5. May 20, 2022, Lab Chemical Sample Log

Date	5/20/2022	5/20/2022	5/20/2022	5/20/2022	5/20/2022
Time	11:37	12:03	16:47	16:50	17:28
EPA 8270E Quartz Filter Client Sample ID			50-Exhaust Baseline	51-Diesel Forklift Exhaust	52-2004 Chevrolet 1500 Gasoline Engine Exhaust - Cold Engine
EPA 8270E Quartz Filter RJLee Report/ Sample ID			W205178-50A	W205178-51A	W205178-52A
Bleed Temp	200C	200C	200C	200C	200C
Contaminant	Mobil Jet Oil II	Mobil Jet Oil II			
Rate	18.8	37.1			
ppmW	5	10			
Manometer in. H2O	0.345	0.34			
Engine Inlet Air Flow kg/s	1.03	1.022			

F US Department of Energy Protective Action Criteria (PAC)

No.	Chemical Compound	CAS Number (CA SRN)	Molecular Weight (MW)	Units of Original Limits	ppm to mg/m³	Molecular Formula	State at 25°C	MP or FP (°C)	BP (°C) @ 760 mm Hg unless Indicated	Vapor Pressure		SG @ 25°C unless indicated	LEL (ppm)	PACs based on AEGLs, ERPGs, or TEELs			Source of PACs PAC-1, PAC-2, PAC-3	Units
										mm Hg	T (°C)			PAC-1	PAC-2	PAC-3		
395	Butanedione, 2,3-; (Diacetyl)	431-03-8	86.1	mg/m3	3.52	CH3COCOCH3	L		88	56.8	25	0.990 @ 15°C		0.02	120	310	TLV-STEL, rat	mg/m3
403	Butanone, 2-; (Methyl ethyl ketone; MEK)	78-93-3	72.11	ppm	2.95	C4H8O	L	-86.64	79.59	75	21.2	0.7999	18000	200_A	2700_A*	4000_A*	AEGL-1, AEGL-2,	ppm
4	Acetaldehyde	75-07-0	44.05	ppm	1.8	C2H4O	L / G	-123.37	20.1	750	20	0.7834 @ 18°C	40000	45_A	270_A	840_A	AEGL-1, AEGL-2,	ppm
7	Acetic acid	64-19-7	60.05	ppm	2.45	C2H4O2	L	16.64	117.9	7.5	14.2	1.0446	40000	5_E	35_E	250_E	ERPG-1, ERPG-2,	ppm
14	Acetone	67-64-1	58.08	ppm	2.37	C3H6O	L	-94.7	56.05	75	1.3	0.7845	26000	200_A	3200_A*	5700_A*	AEGL-1, AEGL-2,	ppm
28	Acrolein	107-02-8	56.063	ppm	2.29	C3H4O	L	-87.7	52.6	274	25	0.840 @ 20°C	28000	0.03_A	0.1_A	1.4_A	AEGL-1, AEGL-2,	ppm
233	Benzaldehyde	100-52-7	106.13	ppm	4.34	C7H6O	L	-57.1	179	0.127	25	1.041	14000	17	43	260	WEEL-STEL,	mg/m3
236	Benzene	71-43-2	78.112	ppm	3.19	C6H6	L	5.49	80.09	75	20	0.8765 @ 20°C	14000	52_A	800_A	4000_A*	AEGL-1, AEGL-2,	ppm
450	Butyraldehyde	123-72-8	72.12	ppm	2.95	C4H8O	L	-96.86	74.7	111	25	.802 @ 20°C	19000	75	430	830	WEEL-TWA x 3,	ppm
452	Butyric acid; (n-Butyric acid) ; butanoic acid	107-92-6	88.12	ppm	3.6	C4H8O2	L	-5.1	163.5	1.65	25	0.959	20000	6	66	400	TEEL-2/11, rat	mg/m3
not listed	Butanonic Acid, 2-methyl																	
713	Crotonaldehyde	4170-30-3	70.09	ppm	2.86	C4H6O	L	-76	102.2	30	25	0.8516 @ 20°C	21000	0.19_A	4.4_A	14_A	AEGL-1, AEGL-2,	ppm
	Cyclobutanone, oxime*																	
771	Decanal	112-31-2	156.3	ppm	6.39	C10.H20.O	L	-5	208.5	0.103	25	0.830 @ 15°C		1.8	19	120	TEEL-2/11,	ppm
772	Decane	124-18-5	142.282	ppm	5.82	C10H22	L	-29.6	174.15	1.43	25	0.7266	8000	6.6	73	440	TEEL-2/11,	ppm
1153	Ethyl alcohol; (Ethanol)	64-17-5	46.07	ppm	1.88	C2H6O	L	-114.14	78.29	75	29.2	0.7893 @ 20°C	33000	1800_E	3300_E*	15000*	ERPG-1, ERPG-2,	ppm
not listed	**Decanoic Acid, Capric acid,or decylic acid**																	
1195	Ethylene glycol	107-21-1	62.08	ppm	2.54	C2H6O2	L	-12.69	197.3		24	1.1135 @ 20°C	32000	30	150	900	MAK-TWA x 3,	ppm
1278	Formaldehyde	50-00-0	30.03	ppm	1.23	CH2O	G	-92	-19.1	750	-19.3	0.815 @ -20°C		0.9_A	14_A	56_A	AEGL-1, AEGL-2,	ppm
1348	Heptanoic acid	111-14-8	130.21	ppm	5.32	C7.H14.O2	L		222.2	0.0056	25	0.918		3.9	43	260	TEEL-2/11,	ppm
1390	Hexanal	66-25-1	100.18	ppm	4.09	C6-H12-O	L	-56.3	131	11.3	25	0.8335 @ 20°C		1.3	14	86	TEEL-2/11, rat	ppm
1396	Hexanoic acid; (caproic acid)	142-62-1	116.18	mg/m3	4.75	C6H12O2	L	-3	205	0.18	20	0.9295	13000	2.2	24	140	TEEL-2/11,	mg/m3
1391	Hexane	110-54-3	86.18	ppm	3.52	C6H14	L	-95.35	68.73	75	9.8	0.6606	11000	260	2900_A*	8600_A**	AEGL-2/11,	ppm
2004	Nonanal	124-19-6	142.27	mg/m3	5.81	C9-H18-O	L					0.820-0.830		0.86	9.5	410	TEEL-2/11,	mg/m3
2007	Nonanoic acid	112-05-0	158.27	mg/m3	6.47	C9.H18.O2	L		254	0.00165	25	0.9055 @ 20°C		15	170	990	TEEL-2/11,	mg/m3
2033	Octanal, 1-; (Octanal; Octanaldehyde)	124-13-0	128.24	mg/m3	5.24	C8-H16-O	L	-23	163.4	1.18	25	0.821 @ 20°C		17	190	1100	TEEL-2/11,	mg/m3
2039	Octanoic acid; (Caprylic acid)	124-07-2	144.24	mg/m3	5.9	C8.H16.O2	L		240			0.91 @ 20°C		30	330	2000	TEEL-2/11,	mg/m3
2070	Ozone	10028-15-6	48	ppm	1.96	O3	G	-193	-111.35	750	-111.5	1.962		0.24	1	10	TEEL-2/11,	ppm
	Pentanal (Valeraldehyde)																	
3039	Pentanoic Acid, (n-Pentanoic acid) Valeric acid;	109-52-4	102.15	mg/m3	4.18	C5.H10.O2	L		186.4	0.196	25	0.940 @ 20°C	16000	2.2	24	140	TEEL-2/11,	mg/m3
3017	Turpentine, (Alpha and beta pinene, 80-56-8)	8006-64-2	140	ppm	5.72	C10.H16 approx	L	-55				0.854-0.868		60	120	1500	TLV-TWA x 3, dog	ppm
2402	Propylene glycol; (1,2-Propanediol)	57-55-6	76.1	mg/m3	3.11	C3H8O2	L	-60	187.6		13	1.0361 @ 20°C	26000	30	1300	7900	WEEL-TWA x 3,	mg/m3
2383	Propionic acid (Propanoic Acid)	79-09-4	74.09	ppm	3.03	C3H6O2	L	-21.5	141.1	10	39.7	0.99815	29000	45	86	510	REL-STEL,	mg/m3
2382	Propionaldehyde	123-38-6	58.08	ppm	2.37	C3H6O	L	-80	48	750	47.7	0.8657	26000	45_A	260_A	840_A	AEGL-1, AEGL-2,	ppm
2735	Tetradecane; (n-Tetradecane)	629-59-4	198.44	ppm	8.11	C14H30	L	5.5	253.7	0.0116	25	0.7628 @ 20°C	5000	3.1	34	200	TEEL-2/11,	ppm
2845	Toluene	108-88-3	92.14	ppm	3.77	C7H8	L	-94.95	110.63	7.5	1.5	0.8623	14000	67_A	560_A	3700_A*	AEGL-1, AEGL-2,	ppm
2871	Tributyl phosphate	126-73-8	266.31	ppm	10.88	C12H27O4P	L	-80	289	75	205	0.9727		1.4	8.3	125	TLV-TWA x 3, rat	ppm
2906	Tridecane	629-50-5	184.41	ppm	7.54	C13H28	L	-5.3	235.4	0.056	25	0.7564		0.0073	0.08	2.3	TEEL-2/11,	ppm
2981	Tri-o-tolyl phosphate; (Triorthocresyl phosphate)	78-30-8	368.39	ppm	15.06	C21H21O4P	L		410			1.17		0.3	13	40	TLV-TWA x 3, TEEL-	ppm
2983	Triphenyl phosphate	115-86-6	326.3	mg/m3	13.34	C18H15O4P	S			1	193.5	1.268 @ 60°C		9	360	2100	TLV-TWA x 3,	mg/m3
3077	Xylene, m- (inlcudes o- (95-47-6) and p- (106-42-3) isomers)	108-38-3	106.17	ppm	4.34	C8H10	L	-47.8	139.07	7.5	23.4	0.8598	11000	560_A	4000_A*	11000_A*	TLV-STEL,	ppm
3078	Xylenes	1330-20-7	106.17	ppm	4.34	C8H10	L				20	0.86 @ 20°C	9000	560	4,000	11,000	AEGL-1, AEGL-2,	mg/m3

Figure F- 1. Department of Energy (DoE) PAC for select bleed air contaminants



CASRN	Compound	Toxicity threshold	Toxicity threshold	Threshold type	Threshold duration	Threshold Source
78-32-0	TCP-mmm	0.3	300	TEEL-1	60 min	US DOE
78-32-0	TCP-mmm	13	13000	TEEL-2	60 min	US DOE
78-32-0	TCP-mmm	40	40000	TEEL-3	60 min	US DOE
1330-78-5	TCP-mmp	0.3	300	TEEL-1	60 min	US DOE
1330-78-5	TCP-mmp	13	13000	TEEL-2	60 min	US DOE
1330-78-5	TCP-mmp	40	40000	TEEL-3	60 min	US DOE
1330-78-5	TCP-mmp	0.3	300	TEEL-1	60 min	US DOE
1330-78-5	TCP-mmp	13	13000	TEEL-2	60 min	US DOE
1330-78-5	TCP-mpp	40	40000	TEEL-3	60 min	US DOE

Figure F- 2. DoE PAC for phosphate isomers

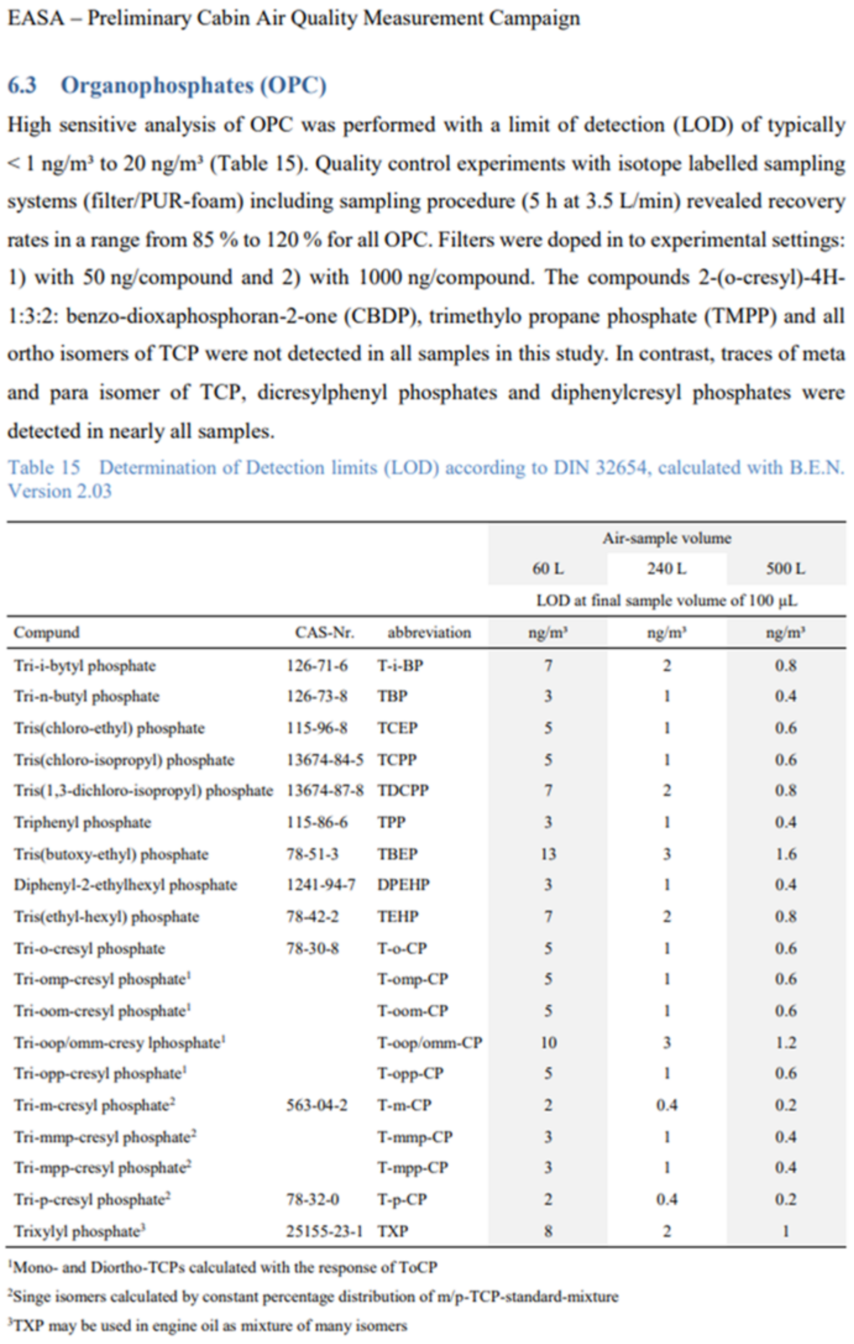
Table F- 1. Protective action criteria for pentanoic acid

Pentanoic Acid Protective Action Criteria
https://cameochemicals.noaa.gov/chemical/1683#section4
Chemical Formula:
Flash Point: 192°F (NTP, 1992)
Lower Explosive Limit (LEL): 1.6 % (USCG, 1999)
Upper Explosive Limit (UEL): 7.6 % (USCG, 1999)
Autoignition Temperature: 752°F (USCG, 1999)
Melting Point: -30.1°F (NTP, 1992)
Vapor Pressure: 1 mmHg at 108°F ; 40 mmHg at 226.0°F; 760 mmHg at 363.9°F (NTP, 1992)
Vapor Density (Relative to Air): 3.52 (NTP, 1992) - Heavier than air; will sink
Specific Gravity: 0.939 (USCG, 1999) - Less dense than water; will float
Boiling Point: 365°F at 760 mmHg (NTP, 1992)
Molecular Weight: 102.13 (NTP, 1992)
Water Solubility: 10 to 50 mg/mL at 72°F (NTP, 1992)
Ionization Energy/Potential: data unavailable
IDLH: data unavailable
AEGLs (Acute Exposure Guideline Levels)
No AEGL information available.
ERPGs (Emergency Response Planning Guidelines)
No ERPG information available.
PACs (Protective Action Criteria)
Chemical Valeric acid; (n-Pentanoic acid) (109-52-4)
EPA Consolidated List of Lists
CISA Chemical Facility Anti-Terrorism Standards (CFATS)
No regulatory information available.
OSHA Process Safety Management (PSM) Standard List
No regulatory information available.

Table F- 2. Protective action criteria for heptanoic acid

Heptanoic Acid Protective Action Criteria
https://cameochemicals.noaa.gov/search/results
HEPTANOIC ACID
A colorless liquid with a pungent odor. Less dense than water and poorly soluble in water. Hence ..
DOT Hazard Label: Corrosive **Flash Point:** greater than 235°F **PAC-3:** 260 ppm
CAS Number: 111-14-8
UN/NA Number: 3265
This chemical is also known as:
N-**HEPTANOIC ACID**
General Description
A colorless liquid with a pungent odor. Less dense than water and poorly soluble in water. Hence floats on water. Very corrosive. Contact may likely burn skin, eyes, and mucous membranes. May be toxic by ingestion, inhalation and skin absorption. Flash point near 200°F.
Flash Point: greater than 235°F (NTP, 1992)
Lower Explosive Limit (LEL): data unavailable
Upper Explosive Limit (UEL): data unavailable
Autoignition Temperature: data unavailable
Melting Point: 16°F (NTP, 1992)
Vapor Pressure: 1 mmHg at 172°F ; 100 mmHg at 320°F; 760 mmHg at 430.7°F (NTP, 1992)
Vapor Density (Relative to Air): data unavailable
Specific Gravity: 0.92 at 68°F (USCG, 1999) - Less dense than water; will float
Boiling Point: 432 to 473°F at 760 mmHg (NTP, 1992)
Molecular Weight: 130.19 (NTP, 1992)
Water Solubility: 1 to 10 mg/mL at 73°F (NTP, 1992)
Ionization Energy/Potential: data unavailable
IDLH: data unavailable
AEGLs (Acute Exposure Guideline Levels)
No AEGL information available.
ERPGs (Emergency Response Planning Guidelines)
No ERPG information available.
PACs (Protective Action Criteria)

G EASA OPC Target List



EASA – Preliminary Cabin Air Quality Measurement Campaign

6.3 Organophosphates (OPC)

High sensitive analysis of OPC was performed with a limit of detection (LOD) of typically < 1 ng/m³ to 20 ng/m³ (Table 15). Quality control experiments with isotope labelled sampling systems (filter/PUR-foam) including sampling procedure (5 h at 3.5 L/min) revealed recovery rates in a range from 85 % to 120 % for all OPC. Filters were doped in to experimental settings: 1) with 50 ng/compound and 2) with 1000 ng/compound. The compounds 2-(o-cresyl)-4H-1:3:2: benzo-dioxaphosphoran-2-one (CBDP), trimethylo propane phosphate (TMPP) and all ortho isomers of TCP were not detected in all samples in this study. In contrast, traces of meta and para isomer of TCP, dicresylphenyl phosphates and diphenylcresyl phosphates were detected in nearly all samples.

Table 15 Determination of Detection limits (LOD) according to DIN 32654, calculated with B.E.N. Version 2.03

			Air-sample volume		
			60 L	240 L	500 L
			LOD at final sample volume of 100 µL		
Compund	CAS-Nr.	abbreviation	ng/m³	ng/m³	ng/m³
Tri-i-bytyl phosphate	126-71-6	T-i-BP	7	2	0.8
Tri-n-butyl phosphate	126-73-8	TBP	3	1	0.4
Tris(chloro-ethyl) phosphate	115-96-8	TCEP	5	1	0.6
Tris(chloro-isopropyl) phosphate	13674-84-5	TCPP	5	1	0.6
Tris(1,3-dichloro-isopropyl) phosphate	13674-87-8	TDCPP	7	2	0.8
Triphenyl phosphate	115-86-6	TPP	3	1	0.4
Tris(butoxy-ethyl) phosphate	78-51-3	TBEP	13	3	1.6
Diphenyl-2-ethylhexyl phosphate	1241-94-7	DPEHP	3	1	0.4
Tris(ethyl-hexyl) phosphate	78-42-2	TEHP	7	2	0.8
Tri-o-cresyl phosphate	78-30-8	T-o-CP	5	1	0.6
Tri-omp-cresyl phosphate[1]		T-omp-CP	5	1	0.6
Tri-oom-cresyl phosphate[1]		T-oom-CP	5	1	0.6
Tri-oop/omm-cresy lphosphate[1]		T-oop/omm-CP	10	3	1.2
Tri-opp-cresyl phosphate[1]		T-opp-CP	5	1	0.6
Tri-m-cresyl phosphate[2]	563-04-2	T-m-CP	2	0.4	0.2
Tri-mmp-cresyl phosphate[2]		T-mmp-CP	3	1	0.4
Tri-mpp-cresyl phosphate[2]		T-mpp-CP	3	1	0.4
Tri-p-cresyl phosphate[2]	78-32-0	T-p-CP	2	0.4	0.2
Trixylyl phosphate[3]	25155-23-1	TXP	8	2	1

[1] Mono- and Diortho-TCPs calculated with the response of ToCP

[2] Singe isomers calculated by constant percentage distribution of m/p-TCP-standard-mixture

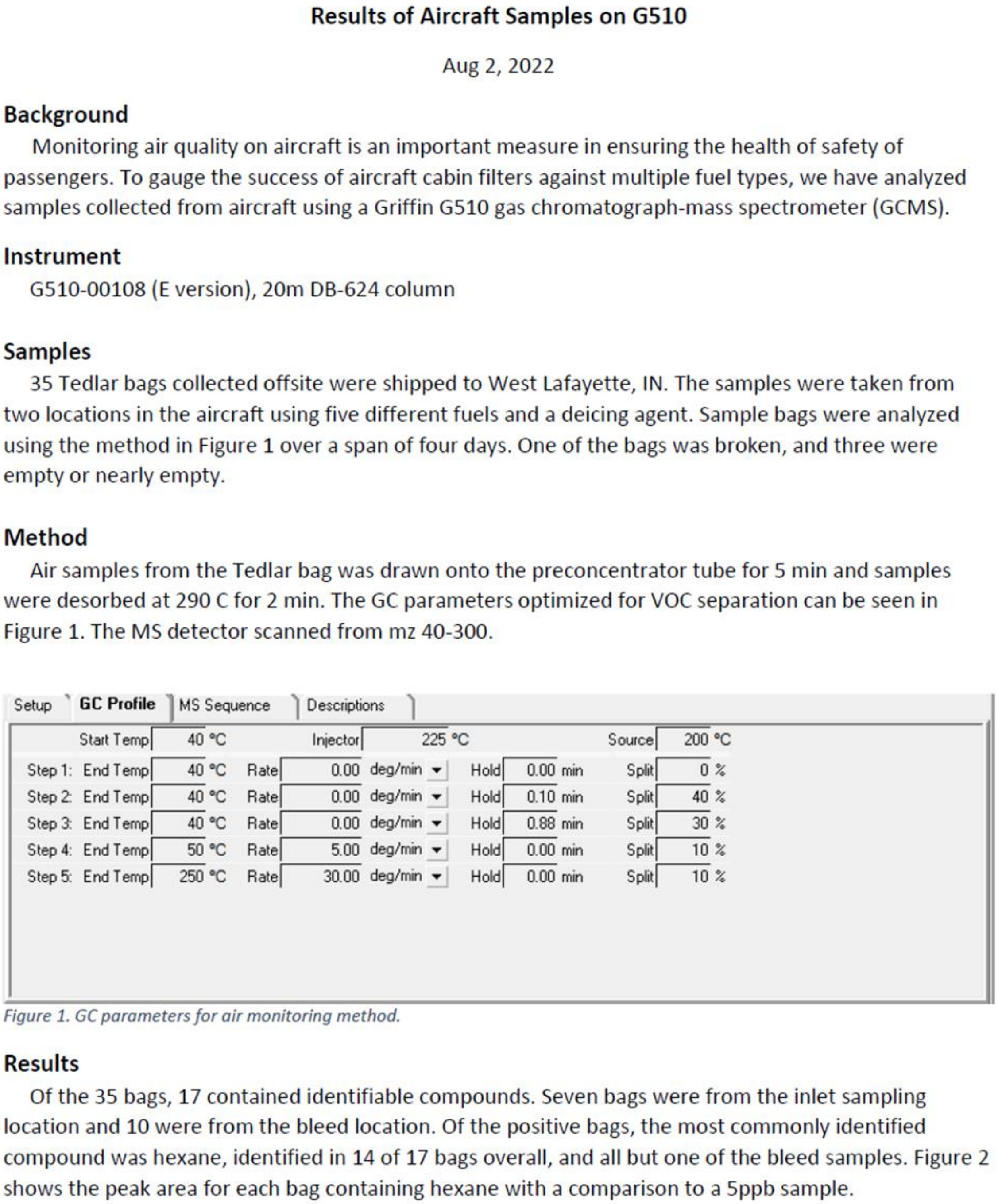
[3] TXP may be used in engine oil as mixture of many isomers

Figure G- 1. EASA Organophosphates (OPC)

https://www.easa.europa.eu/en/downloads/22219/en

H Griffin G510 lab report

Teledyne Griffin (2015) Report



Results of Aircraft Samples on G510

Aug 2, 2022

Background

Monitoring air quality on aircraft is an important measure in ensuring the health of safety of passengers. To gauge the success of aircraft cabin filters against multiple fuel types, we have analyzed samples collected from aircraft using a Griffin G510 gas chromatograph-mass spectrometer (GCMS).

Instrument

G510-00108 (E version), 20m DB-624 column

Samples

35 Tedlar bags collected offsite were shipped to West Lafayette, IN. The samples were taken from two locations in the aircraft using five different fuels and a deicing agent. Sample bags were analyzed using the method in Figure 1 over a span of four days. One of the bags was broken, and three were empty or nearly empty.

Method

Air samples from the Tedlar bag was drawn onto the preconcentrator tube for 5 min and samples were desorbed at 290 C for 2 min. The GC parameters optimized for VOC separation can be seen in Figure 1. The MS detector scanned from mz 40-300.

Start Temp 40 °C   Injector 225 °C   Source 200 °C

Step 1:	End Temp 40 °C	Rate 0.00 deg/min	Hold 0.00 min	Split 0 %
Step 2:	End Temp 40 °C	Rate 0.00 deg/min	Hold 0.10 min	Split 40 %
Step 3:	End Temp 40 °C	Rate 0.00 deg/min	Hold 0.88 min	Split 30 %
Step 4:	End Temp 50 °C	Rate 5.00 deg/min	Hold 0.00 min	Split 10 %
Step 5:	End Temp 250 °C	Rate 30.00 deg/min	Hold 0.00 min	Split 10 %

Figure 1. GC parameters for air monitoring method.

Results

Of the 35 bags, 17 contained identifiable compounds. Seven bags were from the inlet sampling location and 10 were from the bleed location. Of the positive bags, the most commonly identified compound was hexane, identified in 14 of 17 bags overall, and all but one of the bleed samples. Figure 2 shows the peak area for each bag containing hexane with a comparison to a 5ppb sample.

Figure H- 1. Griffin G510 Lab Report- page 1

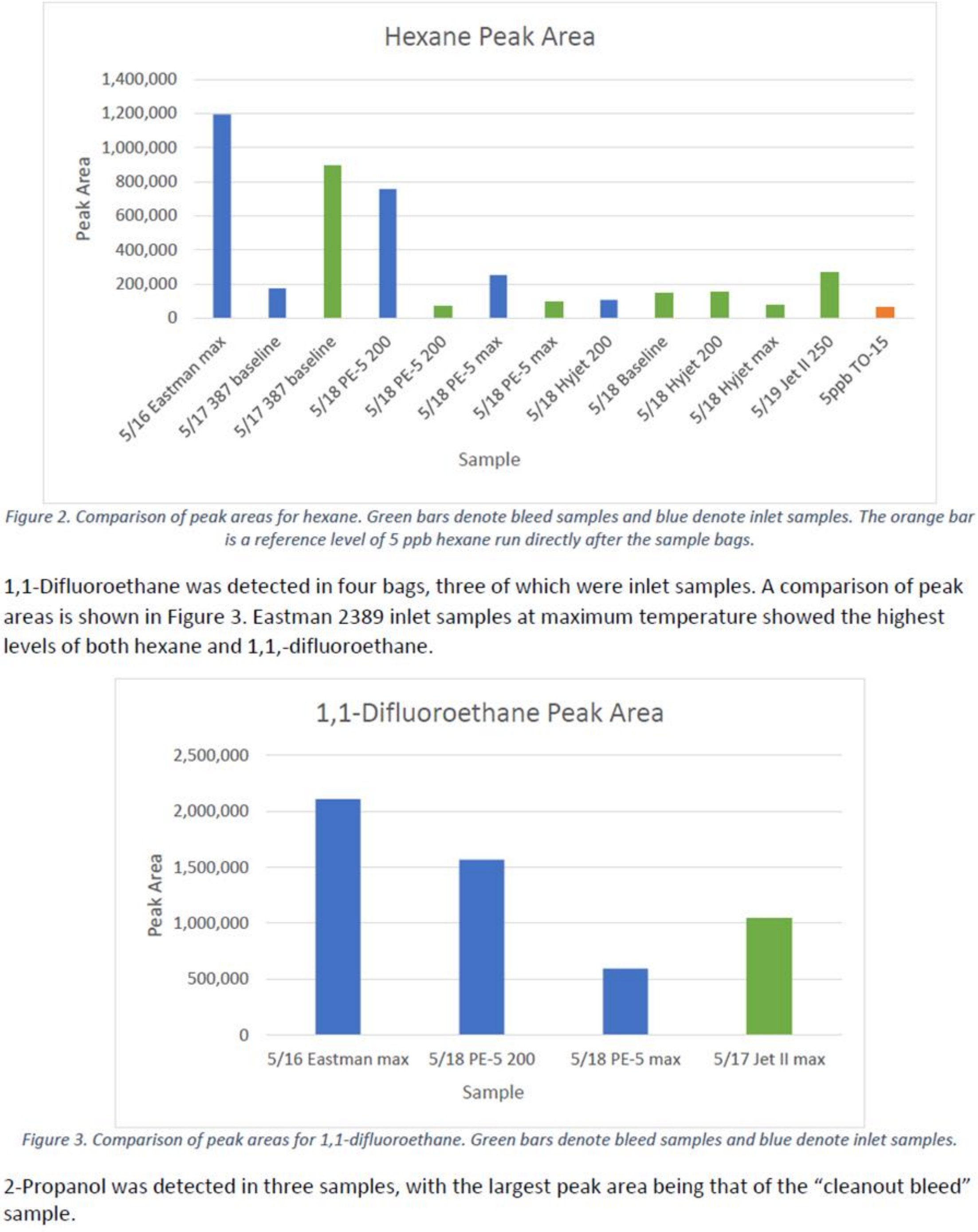


Figure 2. Comparison of peak areas for hexane. Green bars denote bleed samples and blue denote inlet samples. The orange bar is a reference level of 5 ppb hexane run directly after the sample bags.

1,1-Difluoroethane was detected in four bags, three of which were inlet samples. A comparison of peak areas is shown in Figure 3. Eastman 2389 inlet samples at maximum temperature showed the highest levels of both hexane and 1,1,-difluoroethane.

Figure 3. Comparison of peak areas for 1,1-difluoroethane. Green bars denote bleed samples and blue denote inlet samples.

2-Propanol was detected in three samples, with the largest peak area being that of the "cleanout bleed" sample.

Figure H- 2. Griffin G510 Lab Report- page 2

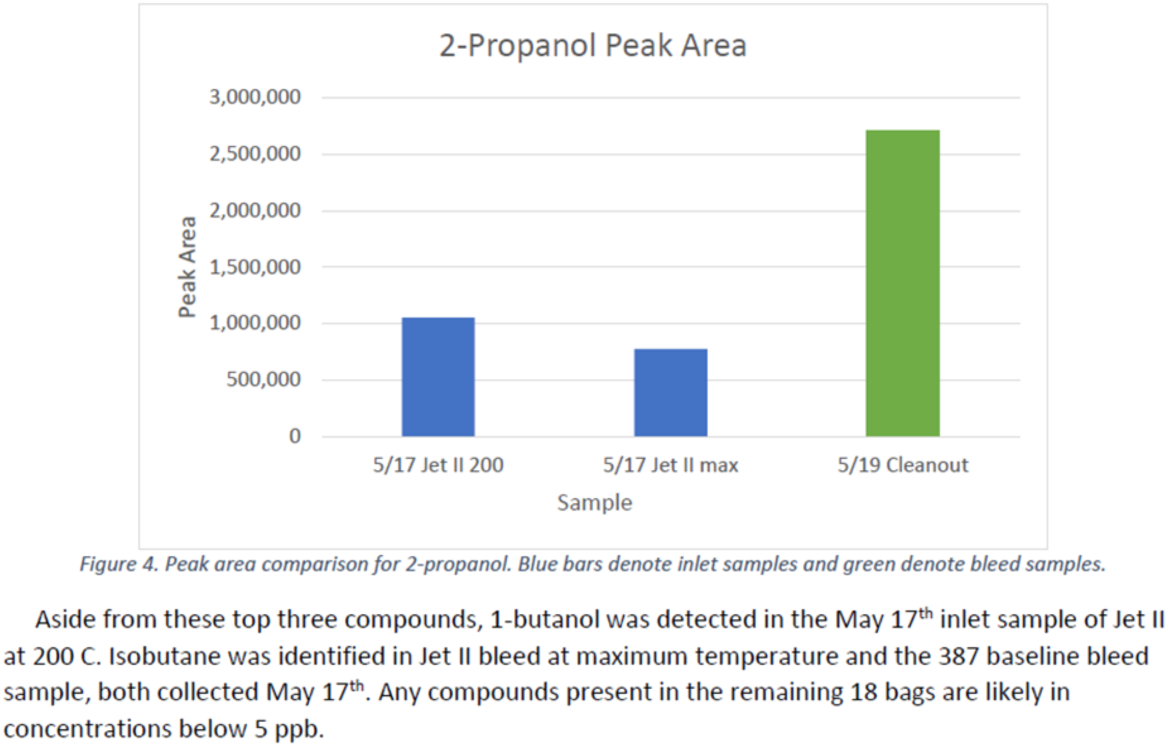


Figure 4. Peak area comparison for 2-propanol. Blue bars denote inlet samples and green denote bleed samples.

Aside from these top three compounds, 1-butanol was detected in the May 17th inlet sample of Jet II at 200 C. Isobutane was identified in Jet II bleed at maximum temperature and the 387 baseline bleed sample, both collected May 17th. Any compounds present in the remaining 18 bags are likely in concentrations below 5 ppb.

Figure H- 3. Griffin G510 Lab Report- page 3

I Instruments

Figure I- 1. TSI 308000 electrostatic classifier

The TSI electrostatic classifier, Part Number 308000 has been discontinued. Information on this equipment is available at:

https://tsi.com/discontinued-products/electrostatic-classifier-3080n/

Figure I- 2. TSI 308701 X-Ray particle neutralizer

The TSI 308701 X-Ray aerosol neutralizer is no longer available. Information is available at:

https://tsi.com/discontinued-products/advanced-aerosol-neutralizer-en/

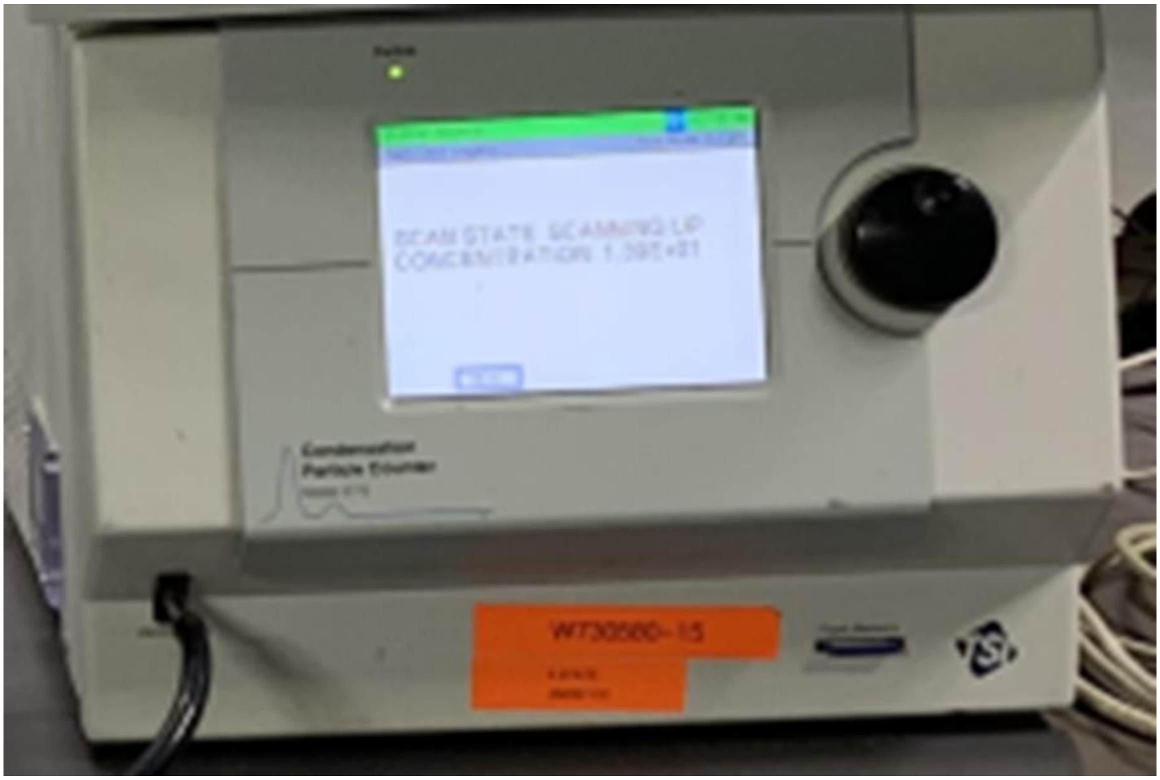


Figure I- 3. TSI 377500 condensation particle counter

The TSI 377500 condensation particle counter (CPC) has been discontinued. Information is available at:

https://tsi.com/discontinued-products/condensation-particle-counter-3775/

Figure I- 4. TSI 3007 handheld condensation particle counter

The TSI 3007 handheld condensation particle counter (CPC) specifications may be found at:

https://tsi.com/products/particle-counters-and-detectors/condensation-particle-counters/condensation-particle-counter-3007/

Figure I- 5. TSI 3910

The TSI NanoScan 3910 specifications are available at:

https://tsi.com/products/particle-sizers/scanning-mobility-particle-sizer-spectrometers/nanoscan-smps-nanoparticle-sizer-3910/

Figure I- 6. Naneos Partector II

Information on the Naneos Partector II is found at:

https://chtechusa.com/products_smd_nanoparticle-naneos-P2.php

Figure I- 7. Pegasor AQ Indoor

The Pegasor AQ Indoor TM was discontinued. Information on the instrument is found at:

https://pegasor.fi/products/aq-indoor

Figure I- 8. Pegasor PPS-M

Information on the Pegasor PPS-M Particle Emissions Sensor is found at:

https://pegasor.fi/products/pps-m

Figure I- 9. First Alert 3120B smoke detector

Boise State University modified an ionization smoke detector and provided several units to KSU for the test. The instruments provided an analog signal which was monitored through the KSU engine monitoring system.

Information on the 3120B Dual Sensor Smoke Alarm is found at:

https://www.firstalert.com/us/en/products/alarms/smoke-alarms/3120b-hardwire-dual-sensor-smoke-alarm-with-battery-backup-3120b/

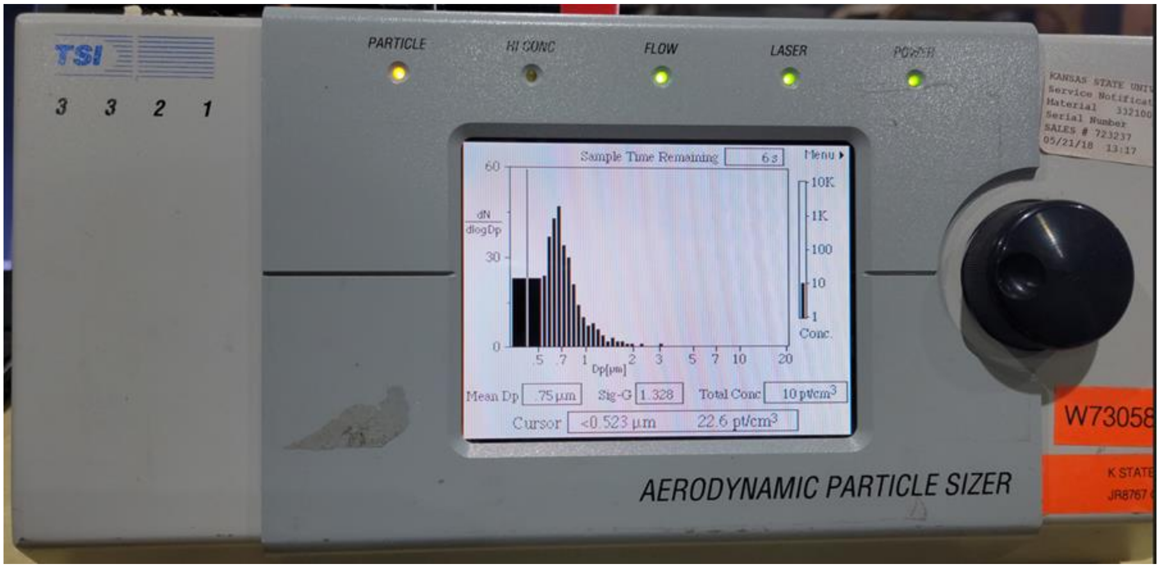


Figure I- 10. TSI 3321 Aerosol Particle Sizer

Information for the TSI 3321 Aerosol Particle Sizer is found at:

https://tsi.com/products/particle-sizers/supermicron-capable-particle-sizer-spectrometers/aerodynamic-particle-sizer-aps-3321/#:~:text=Product%20Details,of%200.37%20to%2020%20microns

Figure I- 11. TSI 3330 Optical Particle Sizer

Information for the TSI 3330 Optical Particle Sizer is found at:

https://tsi.com/getmedia/9728dd3d-5528-4621-9877-a116ee742528/3330_5001323_Web?ext=.pdf

IPS7100-21I000177 (USB)
Serial #: IPS7100-21I000177

PM10
10.103 (ug/m^3)
AQI: 9

PM2.5
9.502 (ug/m^3)
AQI: 40

PM1.0
5.308 (ug/m^3)
AQI: 23

5/17/2022, 3:18:51 PM to 5/17/2022, 3:19:50 PM

View device: IPS7100-21I000177 (USB)

Figure I- 12. Piera Systems IPS-7100 Particle Sensor

Information on the Piera IPS-7100 Particle Sensor is found at:

https://pierasystems.com/products/piera-7100-intelligent-particle-sensor/

Figure I- 13. Canaree^{TM} I5

Specifications for the Piera CanareeTM I5 Particle and VOC sensor can be found at:

https://pierasystems.com/wp-content/uploads/2021/08/Canaree-Datasheet-V1.1.3.pdf

Figure I- 14. TSI Model 7585 Q-Trak XP

Information on the TSI Model 7585 Q-TRAX XP air quality monitor is found at:

https://tsi.com/products/indoor-air-quality-meters-instruments/indoor-air-quality-meters/q-trak-xp-indoor-air-quality-iaq-monitor-7585/

Figure I- 15. Teledyne ACES

Information on the Teledyne Controls ACES cabin air quality monitor is found at:

http://www.teledynecontrols.com/products/cabin-air-monitoring/aces

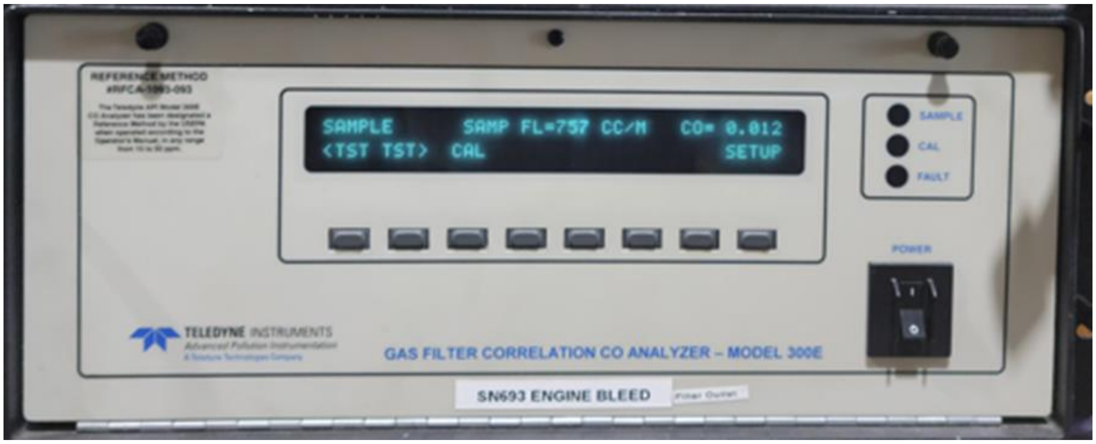


Figure I- 16. Teledyne 300e carbon monoxide analyzer

Information on the Teledyne Air Pollution Instruments Model 300e carbon monoxide analyzer is found at:

https://www.teledyne-api.com/products/carbon-compound-instruments/t300

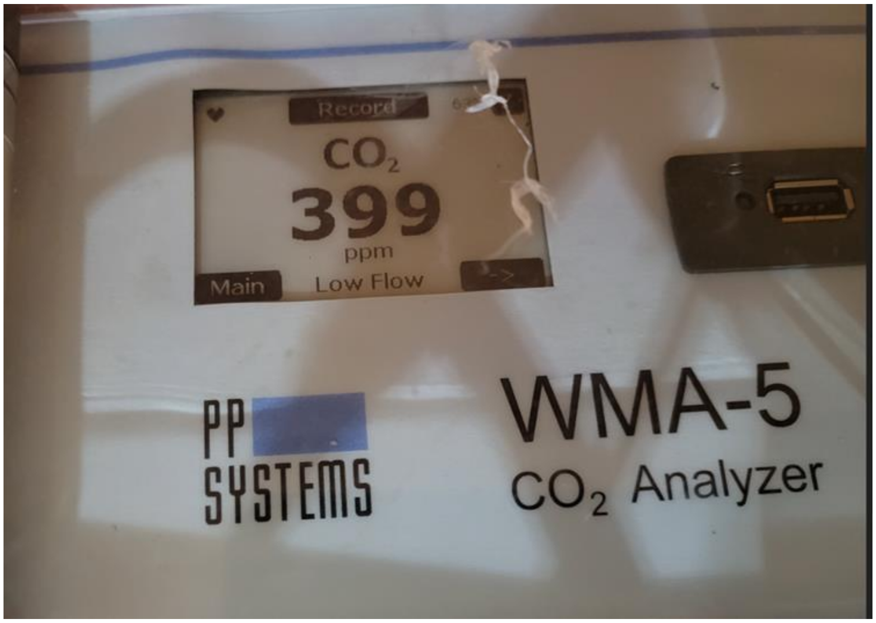


Figure I- 17. PP Systems WMA-5 NDIR carbon dioxide analyzer

Information on the PP Systems Model WMA-5 carbon dioxide analyzer is found at:

https://ppsystems.com/download/technical_manuals/80104-1-WMA-5_Operation_V101.pdf

Figure I- 18. Honeywell ppbRAE 3000

Information for the Honeywell ppbRAE 3000 is found at:

https://sps.honeywell.com/us/en/products/safety/gas-and-flame-detection/portables/ppbrae-3000

Figure I- 19. Astronics metal oxide sensors

Information on Astronics cabin sensing is located at:

https://www.astronics.com/smart-aircraft-system

Figure I- 20. Interscan formaldehyde analyzer

Information on the Interscan D8000 formaldehyde analyzer is found at:

https://cat.gasdetection.com/product/gasd-8000-series-portable-gas-analyzers-formaldehyde-8160-20-00m

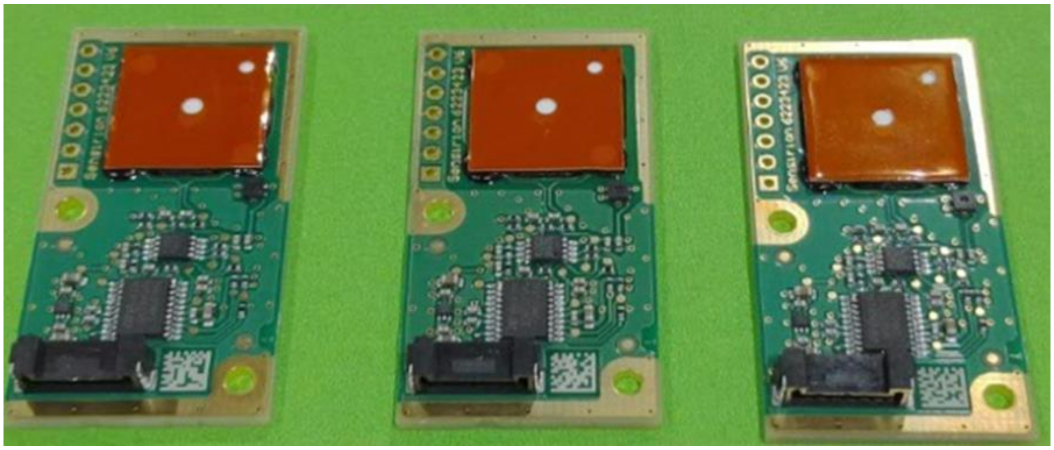


Figure I- 21. Sensirion SFA30

Information on the Sensirion SFA30 Developer Kit is found at:

https://developer.sensirion.com/sensirion-products/sfa30-formaldehyde-sensor-module/

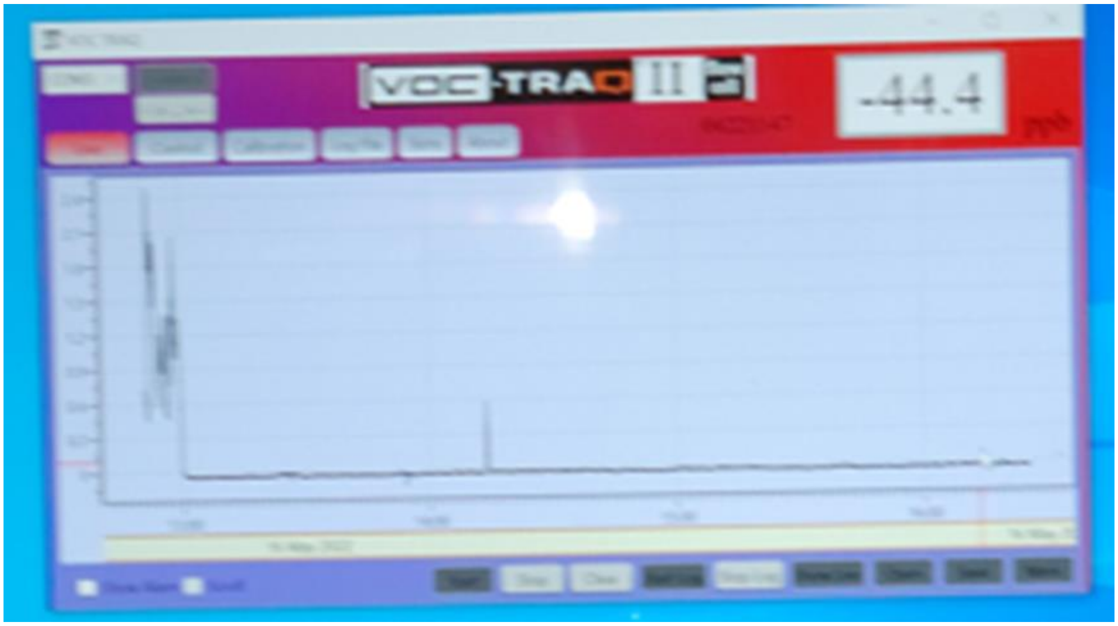


Figure I- 22. AMETEK Mokon II PID

Information on the AMETEK Mokon VOC TRAQ II sensor is found at:

https://www.ametekmocon.com/products/vocdetectors/voctraqiiflowcell

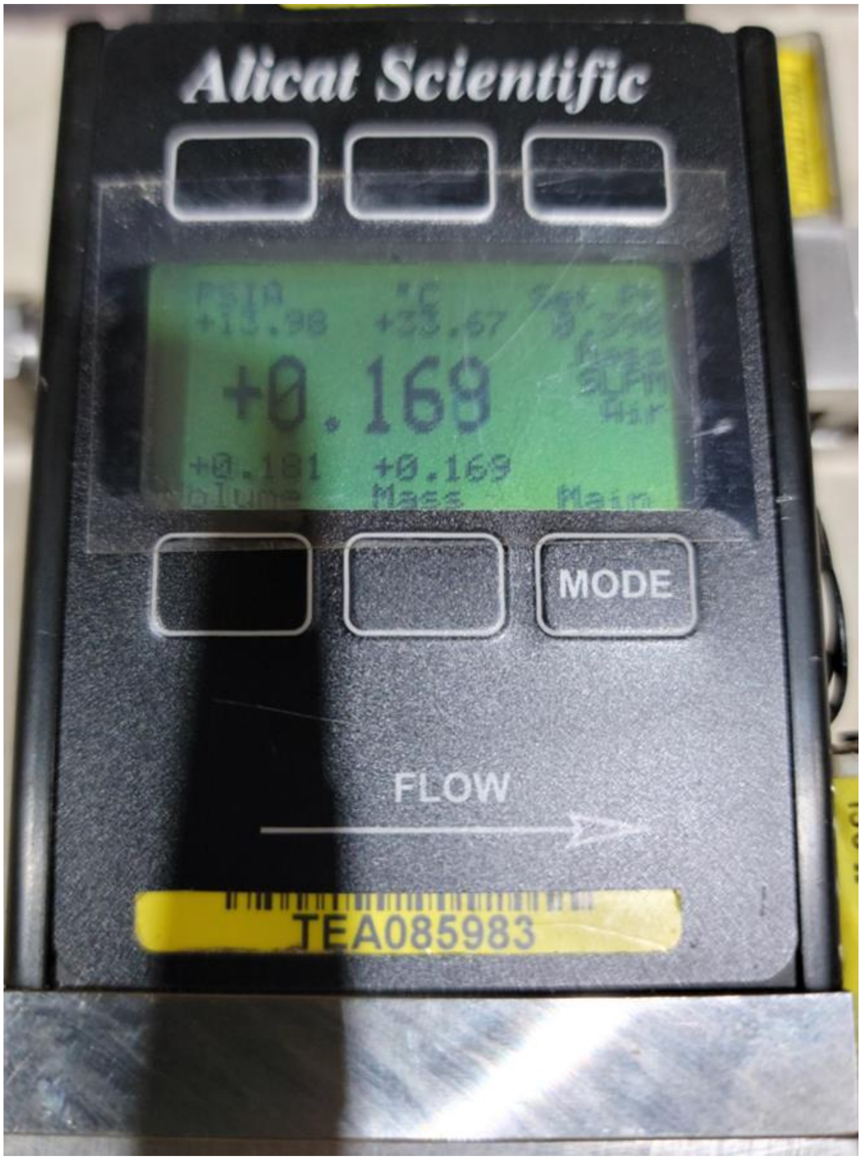


Figure I- 23. Alicat mass flow controllers

Information on Alicat Mass Flowmeter Specifications may be found at:

https://www.alicat.com/documentation/alicat-specification-sheets/

Figure I- 24. TSI Digital flowmeter Model 4043

Information on the TSI Model 4043 Digital Mass Flowmeter may be found at:

https://tsi.com/products/flow-meters,-flow-sensors,-and-flow-analyzers/4000-series-analog-and-digital-flow-meters/mass-flow-meter-4043/

Figure I- 25. New Era Model 300 Pump

Information on the New Era Model 300 Infusion Pump may be found at:

https://www.syringepump.com/NE-300.php

Figure I- 26. Cabin air sensor displays

The Pall Cabin Air Quality Sensor was a prototype and no information is available.

Figure I- 27. Pall cabin air sensor modules

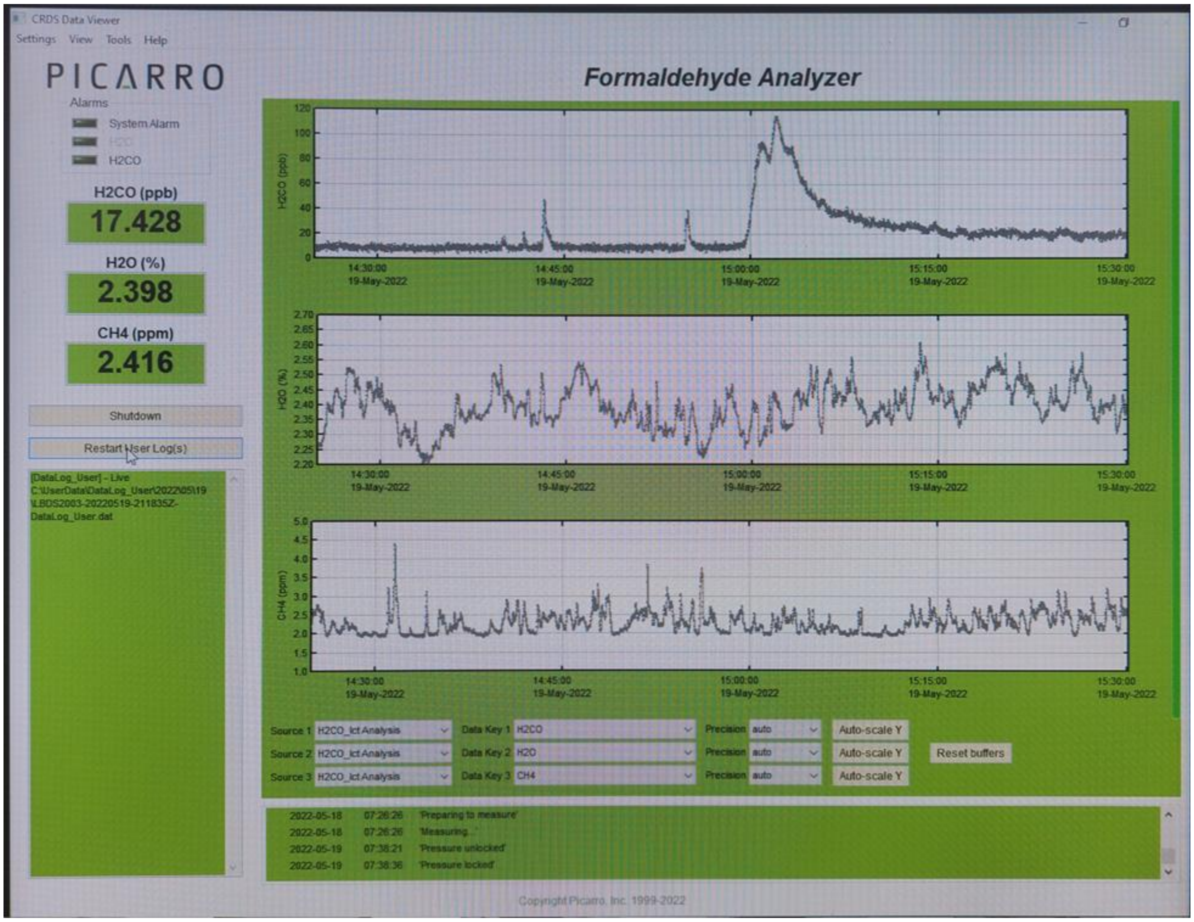
The Pall Cabin Air Quality Sensor was a prototype and no information is available.

J Spectrometers

Figure J- 1. Airsense Aerotracer

Information for the Airsense Aerotracer may be found at:

https://airsense.com/sites/default/files/airsense_aerotracer.pdf



H2CO (ppb) 17.428

H2O (%) 2.398

CH4 (ppm) 2.416

```
[DataLog_User] - Live
C:\UserData\DataLog_User\2022\05\19
\LBDS2003-20220519-211835Z-
DataLog_User.dat
```

Source 1 H2CO_Ict Analysis Data Key 1 H2CO Precision auto

Source 2 H2CO_Ict Analysis Data Key 2 H2O Precision auto

Source 3 H2CO_Ict Analysis Data Key 3 CH4 Precision auto

```
2022-05-18    07:26:26    'Preparing to measure'
2022-05-18    07:26:26    'Measuring...'
2022-05-19    07:38:21    'Pressure unlocked'
2022-05-19    07:38:36    'Pressure locked'
```

Figure J- 2. Picarro G2307 Formaldehyde CRDS

Information for the Picarro G2307 Formaldehyde Cavity Ring-Down Spectroscopy Analyzer may be found at:

https://www.picarro.com/products/g2307_gas_concentration_analyzer/

Figure J- 3. Teledyne FLIR Griffin G510 GC/MS

Information for the Teledyne FLIR Model Griffin G510 GC.\/MS may be found at:

https://www.flir.com/products/griffin-g510?vertical=chem+bio&segment=detection

K Test vehicles

Figure K- 1. Diesel forklift

Figure K- 2. 2004 Chevrolet Silverado Pickup

Figure K- 3. 2022 Toyota Tacoma

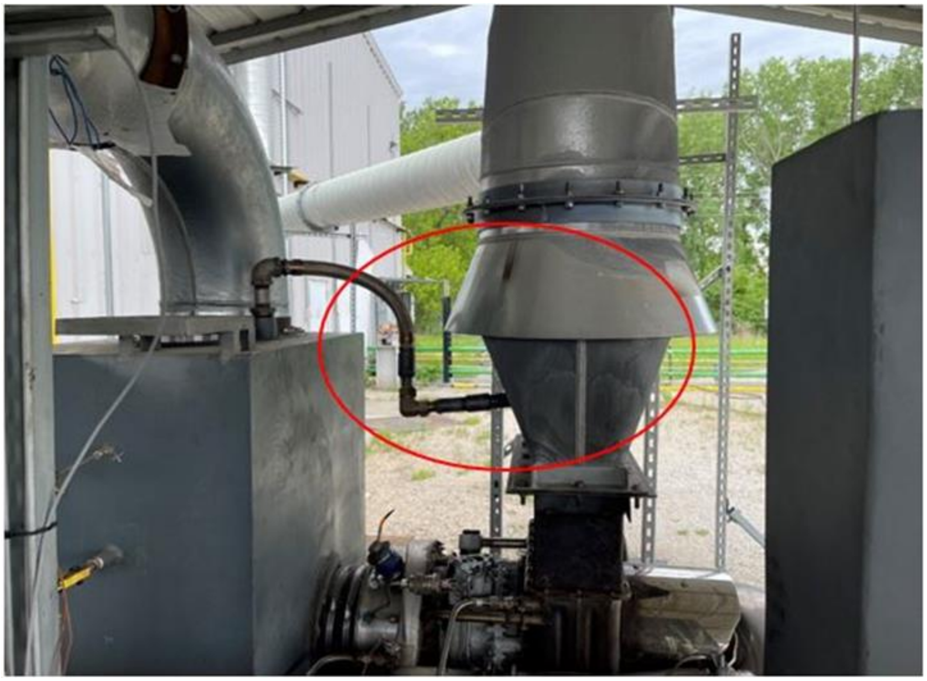
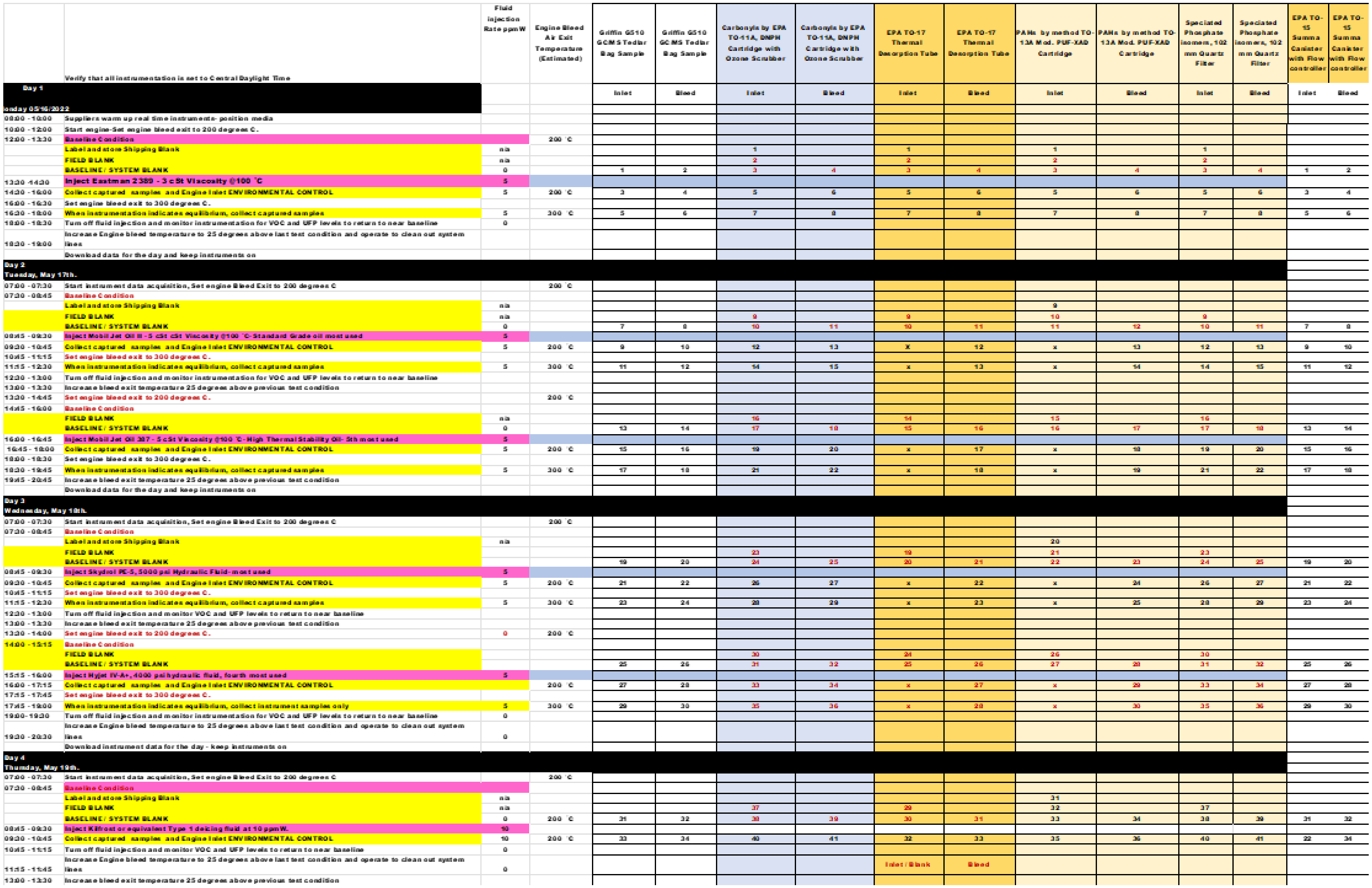


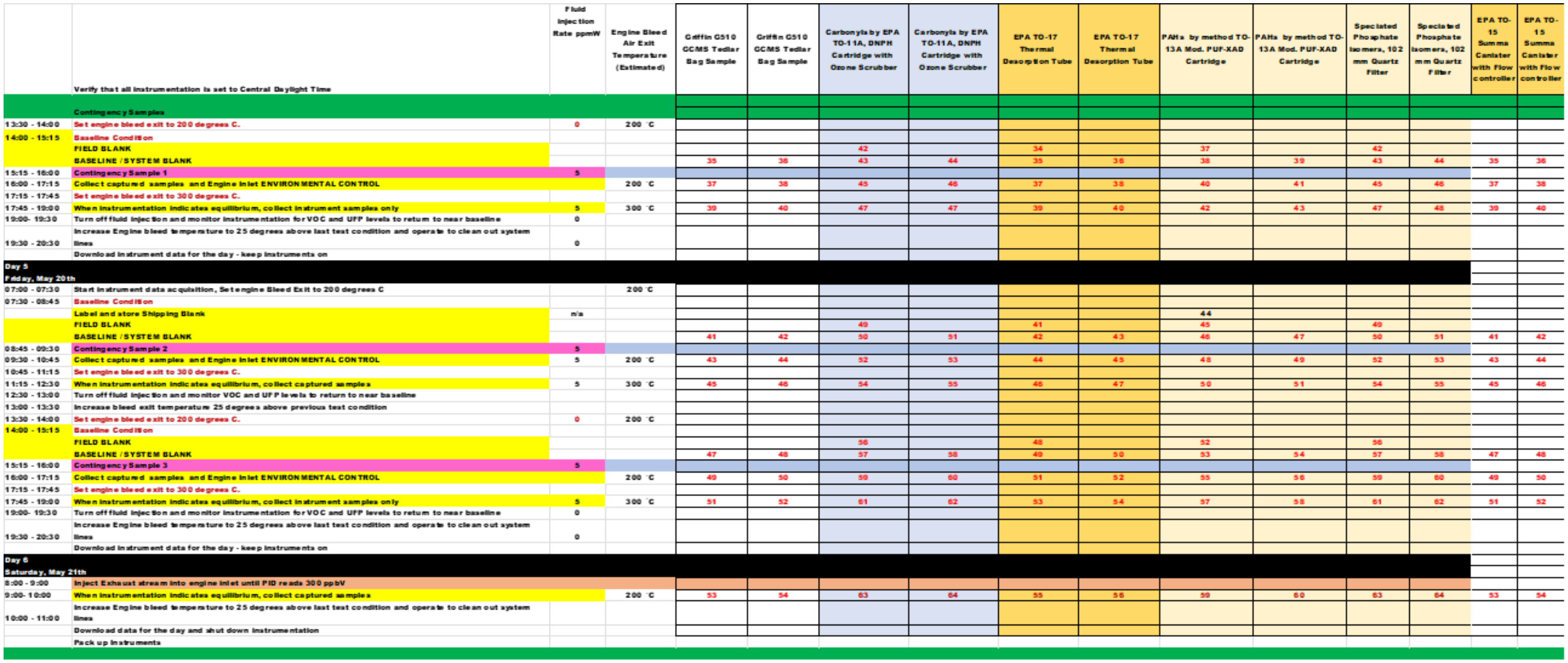
Figure K- 4. Alison 250 C28B turbine engine (exhaust shunt circled in red)

L Test plan with contingency



	Verify that all instrumentation is set to Central Daylight Time	Fluid injection Rate ppmW	Engine Bleed Air Exit Temperature (Estimated)	Griffin G510 GCMS Tedlar Bag Sample	Griffin G510 GCMS Tedlar Bag Sample	Carbonyls by EPA TO-11A, DNPH Cartridge with Ozone Scrubber	Carbonyls by EPA TO-11A, DNPH Cartridge with Ozone Scrubber	EPA TO-17 Thermal Desorption Tube	EPA TO-17 Thermal Desorption Tube	PAHs by method TO-13A Mod. PUF-XAD Cartridge	PAHs by method TO-13A Mod. PUF-XAD Cartridge	Speciated Phosphate isomers, 102 mm Quartz Filter	Speciated Phosphate isomers, 102 mm Quartz Filter	EPA TO-15 Summa Canister with Flow controller	EPA TO-15 Summa Canister with Flow controller
Day 1				Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed	Inlet	Bleed
onday 05/16/2022															
08:00 - 10:00	Suppliers warm up real time instruments- position media														
10:00 - 12:00	Start engine-Set engine bleed exit to 200 degrees C.														
12:00 - 13:30	Baseline Condition		200 °C												
	Label and store Shipping Blank	n/a				1		1		1		1			
	FIELD BLANK	n/a				2		2		2		2			
	BASELINE / SYSTEM BLANK	0		1	2	3	4	3	4	3	4	3	4	1	2
13:30 -14:30	Inject Eastman 2389 - 3 cSt Viscosity @100 °C	5													
14:30 - 16:00	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	3	4	5	6	5	6	5	6	5	6	3	4
16:00 - 16:30	Set engine bleed exit to 300 degrees C.														
16:30 - 18:00	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	5	6	7	8	7	8	7	8	7	8	5	6
18:00 - 18:30	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline	0													
18:30 - 19:00	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines														
	Download data for the day and keep instruments on														
Day 2															
Tuesday, May 17th.															
07:00 - 07:30	Start instrument data acquisition, Set engine Bleed Exit to 200 degrees C		200 °C												
07:30 - 08:45	Baseline Condition														
	Label and store Shipping Blank	n/a								9					
	FIELD BLANK	n/a				9		9		10		9			
	BASELINE / SYSTEM BLANK	0		7	8	10	11	10	11	11	12	10	11	7	8
08:45 - 09:30	Inject Mobil Jet Oil II - 5 cSt cSt Viscosity @100 °C- Standard Grade oil most used	5													
09:30 - 10:45	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	9	10	12	13	X	12	x	13	12	13	9	10
10:45 - 11:15	Set engine bleed exit to 300 degrees C.														
11:15 - 12:30	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	11	12	14	15	x	13	x	14	14	15	11	12
12:30 - 13:00	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline														
13:00 - 13:30	Increase bleed exit temperature 25 degrees above previous test condition														
13:30 - 14:45	Set engine bleed exit to 200 degrees C.		200 °C												
14:45 - 16:00	Baseline Condition														
	FIELD BLANK	n/a				16		14		15		16			
	BASELINE / SYSTEM BLANK	0		13	14	17	18	15	16	16	17	17	18	13	14
16:00 - 16:45	Inject Mobil Jet Oil 387 - 5 cSt Viscosity @100 °C- High Thermal Stability Oil- 5th most used	5													
16:45 - 18:00	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	15	16	19	20	x	17	x	18	19	20	15	16
18:00 - 18:30	Set engine bleed exit to 300 degrees C.														
18:30 - 19:45	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	17	18	21	22	x	18	x	19	21	22	17	18
19:45 - 20:45	Increase bleed exit temperature 25 degrees above previous test condition														
	Download data for the day and keep instruments on														
Day 3															
Wednesday, May 18th.															
07:00 - 07:30	Start instrument data acquisition, Set engine Bleed Exit to 200 degrees C		200 °C												
07:30 - 08:45	Baseline Condition														
	Label and store Shipping Blank	n/a								20					
	FIELD BLANK					23		19		21		23			
	BASELINE / SYSTEM BLANK			19	20	24	25	20	21	22	23	24	25	19	20
08:45 - 09:30	Inject Skydrol PE-5, 5000 psi Hydraulic Fluid- most used	5													
09:30 - 10:45	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	21	22	26	27	x	22	x	24	26	27	21	22
10:45 - 11:15	Set engine bleed exit to 300 degrees C.														
11:15 - 12:30	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	23	24	28	29	x	23	x	25	28	29	23	24
12:30 - 13:00	Turn off fluid injection and monitor VOC and UFP levels to return to near baseline														
13:00 - 13:30	Increase bleed exit temperature 25 degrees above previous test condition														
13:30 - 14:00	Set engine bleed exit to 200 degrees C.	0	200 °C												
14:00 - 15:15	Baseline Condition														
	FIELD BLANK					30		24		26		30			
	BASELINE / SYSTEM BLANK			25	26	31	32	25	26	27	28	31	32	25	26
15:15 - 16:00	Inject Hyjet IV-A+, 4000 psi hydraulic fluid, fourth most used	5													
16:00 - 17:15	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL		200 °C	27	28	33	34	x	27	x	29	33	34	27	28
17:15 - 17:45	Set engine bleed exit to 300 degrees C.														
17:45 - 19:00	When instrumentation indicates equilibrium, collect instrument samples only	5	300 °C	29	30	35	36	x	28	x	30	35	36	29	30
19:00-19:30	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline	0													
19:30 - 20:30	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines	0													
	Download instrument data for the day - keep instruments on														
Day 4															
Thursday, May 19th.															
07:00 - 07:30	Start instrument data acquisition, Set engine Bleed Exit to 200 degrees C		200 °C												
07:30 - 08:45	Baseline Condition														
	Label and store Shipping Blank	n/a								31					
	FIELD BLANK	n/a				37		29		32		37			
	BASELINE / SYSTEM BLANK	0	200 °C	31	32	38	39	30	31	33	34	38	39	31	32
08:45 - 09:30	Inject Kilfrost or equivalent Type 1 deicing fluid at 10 ppmW.	10													
09:30 - 10:45	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	10	200 °C	33	34	40	41	32	33	35	36	40	41	22	34
10:45 - 11:15	Turn off fluid injection and monitor VOC and UFP levels to return to near baseline	0													
11:15 - 11:45	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines	0						Inlet / Blank	Bleed						
13:00 - 13:30	Increase bleed exit temperature 25 degrees above previous test condition														

Figure L- 1. May 14- May 19 morning, 2022 test plan



	Verify that all instrumentation is set to Central Daylight Time	Fluid Injection Rate ppmW	Engine Bleed Air Exit Temperature (Estimated)	Griffin G510 GCMS Tedlar Bag Sample	Griffin G510 GCMS Tedlar Bag Sample	Carbonyls by EPA TO-11A, DNPH Cartridge with Ozone Scrubber	Carbonyls by EPA TO-11A, DNPH Cartridge with Ozone Scrubber	EPA TO-17 Thermal Desorption Tube	EPA TO-17 Thermal Desorption Tube	PAHs by method TO-13A Mod. PUF-XAD Cartridge	PAHs by method TO-13A Mod. PUF-XAD Cartridge	Speciated Phosphate Isomers, 102 mm Quartz Filter	Speciated Phosphate Isomers, 102 mm Quartz Filter	EPA TO-15 Summa Canister with Flow controller	EPA TO-15 Summa Canister with Flow controller
	Contingency Samples														
13:30 - 14:00	Set engine bleed exit to 200 degrees C.	0	200 °C												
14:00 - 15:15	Baseline Condition														
	FIELD BLANK					42		34		37		42			
	BASELINE / SYSTEM BLANK			35	36	43	44	35	36	38	39	43	44	35	36
15:15 - 16:00	Contingency Sample 1	5													
16:00 - 17:15	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL		200 °C	37	38	45	46	37	38	40	41	45	46	37	38
17:15 - 17:45	Set engine bleed exit to 300 degrees C.														
17:45 - 19:00	When instrumentation indicates equilibrium, collect instrument samples only	5	300 °C	39	40	47	47	39	40	42	43	47	48	39	40
19:00- 19:30	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline	0													
19:30 - 20:30	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines	0													
	Download instrument data for the day - keep instruments on														
Day 5 Friday, May 20th															
07:00 - 07:30	Start instrument data acquisition, Set engine Bleed Exit to 200 degrees C		200 °C												
07:30 - 08:45	Baseline Condition														
	Label and store Shipping Blank	n/a								44					
	FIELD BLANK					49		41		45		49			
	BASELINE / SYSTEM BLANK			41	42	50	51	42	43	46	47	50	51	41	42
08:45 - 09:30	Contingency Sample 2	5													
09:30 - 10:45	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL	5	200 °C	43	44	52	53	44	45	48	49	52	53	43	44
10:45 - 11:15	Set engine bleed exit to 300 degrees C.														
11:15 - 12:30	When instrumentation indicates equilibrium, collect captured samples	5	300 °C	45	46	54	55	46	47	50	51	54	55	45	46
12:30 - 13:00	Turn off fluid injection and monitor VOC and UFP levels to return to near baseline														
13:00 - 13:30	Increase bleed exit temperature 25 degrees above previous test condition														
13:30 - 14:00	Set engine bleed exit to 200 degrees C.	0	200 °C												
14:00 - 15:15	Baseline Condition														
	FIELD BLANK					56		48		52		56			
	BASELINE / SYSTEM BLANK			47	48	57	58	49	50	53	54	57	58	47	48
15:15 - 16:00	Contingency Sample 3	5													
16:00 - 17:15	Collect captured samples and Engine Inlet ENVIRONMENTAL CONTROL		200 °C	49	50	59	60	51	52	55	56	59	60	49	50
17:15 - 17:45	Set engine bleed exit to 300 degrees C.														
17:45 - 19:00	When instrumentation indicates equilibrium, collect instrument samples only	5	300 °C	51	52	61	62	53	54	57	58	61	62	51	52
19:00- 19:30	Turn off fluid injection and monitor instrumentation for VOC and UFP levels to return to near baseline	0													
19:30 - 20:30	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines	0													
	Download instrument data for the day - keep instruments on														
Day 6 Saturday, May 21th															
8:00 - 9:00	Inject Exhaust stream into engine inlet until PID reads 300 ppbV														
9:00- 10:00	When instrumentation indicates equilibrium, collect captured samples		200 °C	53	54	63	64	55	56	59	60	63	64	53	54
10:00 - 11:00	Increase Engine bleed temperature to 25 degrees above last test condition and operate to clean out system lines														
	Download data for the day and shut down instrumentation														
	Pack up instruments														

Figure L- 2. May 19 afternoon – May 21, 2022 test plan