THERMAL OXIDIZER PERFORMANCE TEST REPORT CHEMOURS COMPANY FAYETTEVILLE WORKS

PREPARED FOR:

THE CHEMOURS COMPANY
FAYETTEVILLE WORKS PLANT
22828 NC HWY 87 WEST
FAYETTEVILLE, NC 28306

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FOCUS PROJECT NO. P-001446

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Source Emissions Testing of a Thermal Oxidizer and Scrubber System Stack, The Chemours Company – Fayetteville, North Carolina, Ramboll, March 2021.

Summaries of the following analyses performed by Eurofins TestAmerica are presented as Appendix D of the Ramboll report noted above. The complete analytical data packages are provided with this report on compact disk.

Eurofins TestAmerica Analytical Data Packages	
Data Pkg. No.	**Description**
140-21803-1	Final Report-Monomer Line #1 Method 18
140-21804-1	Final Report-Polymer Line #2 Method 18
140-21805-1	Final Report-Waste Gas Line Method 18 QC
140-21799-1	Final Report-Stack Gas Method 18
140-21800-1	Final Report-Stack Gas Method 18 QC
140-21801-1	Final Report-Stack Gas Method 0010
140-21802-1	Final Report-Stack Gas Method 0010 QC
140-21806-1	Final Report-Process Water Samples

List of Acronyms

amu	atomic mass units
ASTM	American Society for Testing and Materials
CaF_2	calcium fluoride
CF_4	tetrafluoromethane
CO	carbon monoxide
CO_2	carbon dioxide
COC	chain of custody
COF_2	carbonyl difluoride
DE	destruction efficiency
DQO	data quality objective
DMC	dimethyl carbonate
dscf	dry standard cubic feet (EPA standard at 68°F, 1 atmosphere)
dscm	dry standard cubic meter (EPA standard at 68°F, 1 atmosphere)
E-1	Heptafluoropropyl-1,2,2,2-tetrafluoroethyl ether (Fluoroether E-1)
EPA	Environmental Protection Agency
HF	hydrogen fluoride (gas) or hydrofluoric acid (aqueous)
HFPO	hexafluoropropylene oxide (HFPO), a.k.a., “HFPO monomer” or simply “monomer”
HFPO-DA	hexafluoropropylene dimer acid or C_3-dimer, a.k.a., “HFPO dimer”, “dimer acid”, “dimer”, or Gen X
HFPO-DAF	hexafluoropropylene dimer acid fluoride, a.k.a., “HFPO dimer fluoride”, “dimer acid fluoride”, or simply “dimer fluoride”
HFPO-DOCH$_3$	HFPO dimer, methyl ester
HPLC/MS/MS	high performance precision liquid chromatography/tandem mass spectrometry
hr	hour
GC/MS	gas chromatography/mass spectrometry
LCS	laboratory control sample
lpm	liters per minute
MDL	method detection limit
min	minute
MMBtu	million British thermal units
2-MTP	methyl-2-methoxy-tetrafluoro-propionate
NCDAQ	North Carolina Department of Air Quality
N_2	nitrogen
O_2	oxygen
OPL	operating parameter limit
OTM	Other Test Method
PFAS	per- or poly-fluorinate alkyl substance
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
psia	pounds per square inch absolute (psig + atmospheric pressure)
psig	pounds per square inch gauge
QA	quality assurance
QC	quality control
RFA	request for analysis
RL	reporting limit
RPD	relative percent difference
RSD	relative standard deviation
SOP	standard operating procedure
SVOC	semi-volatile organic compound
TFE	tetrafluoroethylene
VOC	volatile organic compound

1.0 EXECUTIVE SUMMARY

This report presents the results of per- and poly-fluoroalkyl substance (PFAS) destruction efficiency (DE) performance testing conducted January 26-28, 2021 on the thermal oxidizer located at The Chemours Company FC, LLC (Chemours) facility, Fayetteville, North Carolina. Per the consent order, "*Chemours shall demonstrate that the thermal oxidizer controls all PFAS at an efficiency of 99.99%"*. Chemours also holds a Title V permit which contains the same thermal oxidizer requirements and requires the testing protocol *"to address how the Permittee will ensure the Thermal Oxidizer and 4-Stage Scrubber System will achieve the emission reduction* [of 99.99%]*, including the use of a surrogate for all PFAS, such as the hexafluoropropylene oxide (HFPO)."* A test plan delineating the thermal oxidizer DE performance test target operating conditions, and the sampling and analytical protocols, was submitted to the North Carolina Department of Air Quality (NCDAQ) on December 9, 2019. Chemours conducted the initial thermal oxidizer performance test on February 28-29, 2020 in substantial conformance with the approved test plan. This report presents the PFAS DE results of the first recurring performance test.

During the test, both the monomer and polymer manufacturing operations directed PFAS-bearing waste gases to the thermal oxidizer. The test program characterized the waste gas feed materials and measured the emission rates of five (5) target PFAS compounds:

- HFPO (Hexafluoropropylene oxide), a.k.a., "HFPO monomer" or simply "monomer",
- HFPO-DA (Hexafluoropropylene Dimer Acid or C_3-Dimer), a.k.a., "HFPO dimer", "dimer acid", "dimer" or "Gen X",
- HFPO-DAF (Hexafluoropropylene Dimer Acid Fluoride),
- COF_2 (Carbonyl Difluoride), and
- Fluoroether E-1 (Heptafluoropropyl-1,2,2,2-tetrafluoroethyl ether).

System DE performance was calculated based on the sum of the system inlet feed rates and sum of the stack emissions rates of these five (5) compounds. "Total PFAS" is the arithmetic sum of HFPO, HFPO-DA, HFPO-DAF, COF_2, and Fluoroether E-1 under these conditions. The total PFAS DE results are summarized in Table 1-1.

Table 1-1. Thermal Oxidizer Total PFAS Destruction Efficiency
Chemours Company FC, LLC, Fayetteville, North Carolina, January 26-28, 2021

Run 1	Run 2	Run 3	Average
99.99920%	99.99968%	99.99963%	99.99951%

The total PFAS DE performance exceeded 99.999% during all three (3) test runs. The balance of this report presents the details of the testing performed.

2.0 INTRODUCTION

2.1 FACILITY BACKGROUND INFORMATION

The Chemours Company FC, LLC (Chemours) manufactures chemicals, plastic resins, plastic sheeting, and plastic film at the facility located at 22828 NC Highway 87 West, Fayetteville, Bladen County, North Carolina (the facility). Under the consent order executed and filed February 25, 2019 Chemours was required to install a thermal oxidizer for control of per- and poly-fluoroalkyl substance (PFAS) process stream emissions from identified manufacturing operations. A test plan delineating the thermal oxidizer destruction efficiency (DE) performance test target operating conditions, and the sampling and analytical protocols, was and submitted to the North Carolina Department of Air Quality (NCDAQ) on December 9, 2019. NCDAQ gave approval of the test plan via letter dated January 27, 2020. The initial DE performance test was conducted February 28-29, 2020. This test report documents the operating conditions, and the sampling and analytical test results of the first recurrent DE performance test conducted January 26-28, 2021 following the protocols of the same test plan previously approved by NCDAQ.

2.2 BRIEF ENGINEERING DESCRIPTION

The thermal oxidizer and its associated 4-stage scrubber are identified in the Air Quality Permit respectively as control devices NCD-Q1 and NCD-Q2. Please refer to Figure 2-1. The thermal oxidizer is a 10 million BTU per hour (MMBtu), natural gas-fired device. Waste gases from the manufacturing operations process streams are collected via header systems, compressed and delivered by pipeline to the thermal oxidizer for destruction of the entrained PFAS compounds. Thermal oxidizer emissions are treated in the scrubber system to control hydrogen fluoride (HF) generated by PFAS compound combustion. The scrubber system consists of a 4-stage packed bed column with three water scrubbing stages and one caustic scrubbing stage.

2.3 THERMAL OXIDIZER TEST PROTOCOL DEVELOPMENT

The properties of each PFAS compound are sufficiently unique such that no singular sampling and analysis approach is appropriate for a comprehensive characterization of all PFAS compounds handled at Chemours Fayetteville Works. The physical and chemical properties of each of the potential target PFAS compounds must be considered when developing a sampling and analytical protocol.

The sampling and analytical protocols employed for this test program were developed by Chemours through consultation with Eurofins TestAmerica, Inc. The technical discussion presented in the following sections underlies the sampling and analytical technical basis used to conduct this performance test, and the performance conclusions derived from the results presented in this test report.

2.3.1 Test Plan Target Compounds

The thermal oxidizer DE performance test program was designed based on the characterizations of site-specific target PFAS compounds. The five (5) target compounds were:

- HFPO (Hexafluoropropylene oxide), a.k.a., “HFPO monomer” or simply “monomer”,
- HFPO-DA (Hexafluoropropylene Dimer Acid or C_3-Dimer), a.k.a., “HFPO dimer”, “dimer acid”, “dimer” or “Gen X”,
- HFPO-DAF (Hexafluoropropylene Dimer Acid Fluoride),
- COF_2 (Carbonyl Difluoride), and
- Fluoroether E-1 (Heptafluoropropyl-1,2,2,2-tetrafluoroethyl ether).

Table 2-1 presents a summary of the chemical composition and structural information, and key chemical and physical property data for the five (5) PFAS compounds targeted for this test program.

The base compounds handled and used at the Fayetteville facility are HFPO and HFPO-DA. HFPO-DAF is a synthetic precursor to HFPO-DA in the chemical process. The molecular structure of HFPO-DAF is identical to HFPO-DA except fluorine (F) is substituted in place of the hydroxyl (-OH) group. This difference between HFPO-DA and HFPO-DAF has substantial impact on the physical properties and chemical reactivity of these otherwise structurally similar compounds. An additional reactant compound, COF_2, is a major constituent in the waste gas. Fluoroether E-1 is a thermal decarboxylation product of HFPO-DA and appears as an intermittent major constituent in the waste gas. The combined feed rates to the thermal oxidizer and the concurrently measured emission rates of HFPO, HFPO-DA, HFPO-DAF, COF_2, and Fluoroether E-1 from the thermal oxidizer were established to demonstrate PFAS DE performance.

2.3.2 Sampling and Analytical Design Basis

HFPO, HFPO-DAF, and COF_2 react with methanol (MeOH) to form ester compounds as depicted below:

- HFPO + MeOH → 2-MTP + 2HF
- HFPO-DAF + MeOH → HFPO-$DOCH_3$ + HF
- COF_2 + 2MeOH → DMC + 2HF.

The 2-MTP stands for methyl-2-methoxy-tetrafluoro-propionate. The HFPO-$DOCH_3$ stands for HFPO dimer, methyl ester. The DMC stands for dimethyl carbonate. All three (3) ester compounds are analyzed via SW-846 Method 8260. The sampling and analytical strategy for HFPO, HFPO-DAF, and COF_2 is designed based on the reaction of these compounds with methanol to form derivative reaction products, and quantifying them based on analysis of their reaction products.

The Fluoroether E-1 and HFPO-DA sampling and analytical strategy was designed based on capturing the compounds via condensation and dissolution in the methanol impingers. Fluoroether E-1 is captured as a volatile organic compound (VOC), and then quantified via direct analysis using SW-846 Method

8260. HFPO-DA is captured as a semi-volatile organic compound (SVOC) and then quantified via direct analysis using EPA Method 537.

2.3.3 Developed Sampling Methods

Two (2) sampling methods were developed and employed for this test program. Please refer to Figures 2-2 and 2-3. One method is based on EPA Method 18. The second is based on SW-846 Method 0010. [Note: The modified SW-846 Method 0010 sampling methodology set forth in the approved test plan and used during this test program is substantially equivalent to Other Test Method-45 (OTM-45) posted to EPA's Air Emission Measurement Center (EMC) website on January 13, 2021:

https://www.epa.gov/sites/production/files/2021-01/documents/otm_45_semivolatile_pfas_1-13-21.pdf].

The following sections describe the sampling methods, the associated specialized techniques, and their application during this test program.

2.3.3.1 Modified Method 18 Sampling

The Modified Method 18 (MM18) sampling train consists of six (6) PFA fluoropolymer impingers and connectors configured in series. The impingers are charged with methanol. For sampling, the impingers are immersed in a methanol bath chilled using dry ice to maintain a temperature of -73°C (-100°F) or less. The principle of operation is to capture the target PFAS compounds by condensation and/or chemical reaction within the methanol media. The six (6) successive impingers are designed to provide sufficient condensing, absorbing, and reaction capacity to capture the target PFAS analytes. The sampling train is connected to a dry gas meter sampling system to measure the volume of dry gas sampled. At the conclusion of a test run, the six (6) sampling train impingers are recovered as discrete (individual) samples and analyzed separately.

The Modified Method 18 sampling method captures the target PFAS compound vapors via condensing and/or reaction with methanol as the sampled gas is sparged through the successive chilled methanol matrix. Two (2) of the five (5) target compounds, Fluoroether E-1 and HFPO-DA, are captured by simply condensing them from the gas stream and dissolving them in methanol. Three (3) of the five (5) compounds, HFPO, HFPO-DAF, and COF_2, react with the methanol to form ester compounds as previously described. The HFPO and COF_2 have respective boiling points of -28°C and -85°C, but their reaction with methanol to form the higher boiler point derivative ester compounds is key to facilitating the measurement of these compounds. The boiling points of the ester compounds formed from HFPO and COF_2 are higher and therefore easier to recover and retain similar to standard EPA volatile organic compound (VOC) analytes. Post-sampling preservation of these samples is by refrigeration using wet ice to 4°C.

2.3.3.2 Modified Method 0010 Sampling

Based on its boiling point of 151°C, HFPO-DA is classified by EPA as a semi-volatile organic compound (SVOC) that can potentially condense and possibly attach to particulate matter. Therefore, to accurately measure the stack emissions of HFPO-DA, the sampling is conducted using an iso-kinetic sampling method.

The sampling train is generally configured like a standard Method 0010 sampling train with a heated probe and filter, condenser coil, XAD-2 resin cartridge, deionized water impingers, and a silica gel impinger. An added feature is a second XAD-2 resin cartridge located between the last deionized water impinger and the silica gel impinger. The purpose of the second XAD-2 resin cartridge is to act as a quality indicator to assess possible target analyte breakthrough. Other specialized aspects of the Modified Method 0010 sampling are:

- During sampling collection, the sampling probe temperature is maintained a few degrees above the dew point of the moisture in the gas stream, well below the normal Method 5 operating temperature range of 248°F (120°C) (to preclude thermal decarboxylation of HFPO-DA to form Fluoroether E-1)
- Maintaining the coil condenser and XAD-2 resin jacket as cold as reasonably possible below the normal Method 0010 prescribed maximum of 68°F (20°C) temperature for best possible conditions for HFPO-DA retention on the resin, and
- Use of 95% methanol / 5% NH_4OH solution as the recovery solvent for the rinsing of sampling train components to recover HFPO-DA from glassware surfaces.

A total of seven (7) sample fractions are generated during the Modified Method 0010 sampling train recovery:

- Particulate filter
- Solvent (95% methanol / 5% NH_4OH) rinses of the probe, nozzle, and the front-half of the filter holder
- Primary XAD-2 resin tube
- Back-half of the filter holder, coil condenser, and connecting glassware 95% methanol / 5% NH_4OH solvent glassware rinses
- Condensate and impinger contents of Impingers #1, #2 and #3 charged with deionized (DI) water and includes DI water rinses of the glassware
- Impingers #1, #2 and #3 solvent (95% methanol / 5% NH_4OH) glassware rinses as a separate sample (NOT combined with the impinger water and DI water rinses), and
- Breakthrough XAD-2 resin tube.

2.3.4 Sampling Locations and Methods

The test program sampling campaign was designed to characterize the feed materials to the thermal oxidizer and the corresponding emissions of the target PFAS compounds. The sampling locations are:

1) the monomer waste gas feed line (Line #1),

2) the polymer waste gas feed line (Line #2), and

3) the thermal oxidizer/scrubber stack.

The sampling techniques used at each location are discussed in the following sections. During testing, all locations were sampled concurrently.

2.3.4.1 Waste Gas Feed Line Sampling

The two (2) waste gas feed lines to the thermal oxidizer were sampled separately at points on the 3-inch lines from the accumulator tanks to the thermal oxidizer. The gas pressure in these lines is nominally 10-30 psig. To perform the sampling, Chemours designed, fabricated, and installed permanent sampling probes in these lines. Please refer to Figure 2-4. The permanently installed probes include a nozzle centered in the line and oriented to face into the stream flow, similar to the orientation of an isokinetic sampling probe when sampling stack gas. The installed sampling probe apparatus includes Swagelok® connectors that allow for connection of the sampling trains to the feed lines without line breaks. Ball valves allow for starting and stopping the flow of pressurized gas. The “bleed” connection allows for connection to a compressed nitrogen line to purge and clear the sampling location of any buildup of liquid or debris prior to sampling, and after sampling is completed. The previously described Modified Method 18 sampling train was used to sample the waste gas lines for the five (5) target PFAS compounds: HFPO, HFPO-DA, HFPO-DAF, COF_2, and Fluoroether E-1.

The sampling train meter box includes a needle control valve. No vacuum pump is required; the waste gas feed line pressure provides the sampled gas motive force. The meter box needle control valve is used to throttle and control the flow rate of the waste gas through the sampling train. The dry gas meter is used to measure the dry gas flow rate and the total volume of dry inert gas sampled.

The two (2) waste gas feed lines were sampled concurrently using two sampling trains, one on each of the waste gas feed lines. The target sampling rate was maintained at approximately 0.50 liters per minute. Waste gas feed lines sampling was also performed concurrently with the stack gas emissions sampling at the thermal oxidizer/scrubber stack. Dry gas meter flow, pressure, and temperature data were used to determine the total mass of dry gas sampled. Nitrogen is used in the system as the inert sweep gas for the waste gases in the vent header systems. Therefore, the waste gas dry gas composition was assumed to be 100% nitrogen and assigned a molecular weight of 28 amu. Pre- and post- sampling impinger differential weights were used to determine the mass of organic constituent vapors condensed in the sampling train from the sampled waste gases.

2.3.4.2 Stack Gas Modified Method 18 Sampling

A Modified Method 18 sampling train was used to sample the stack gas for four (4) of the five (5) target PFAS compounds: HFPO, HFPO-DAF, COF_2, and Fluoroether E-1. The Modified Method 18 sampling protocol is similar as described for the waste gas feed lines except use of a vacuum pump equipped metering system was required to draw the sampled stack gas through the sampling train. The target sampling rate was 1.5-2.0 liters per minute. Dry gas meter flow, pressure, and temperature data were used to determine the total volume of dry gas sampled. Dry gas molecular weight was determined via Method 3A analysis of the dry gas meter exhaust.

2.3.4.3 Stack Gas Modified Method 0010 Sampling

As previously noted, HFPO-DA is classified as a SVOC by EPA that can potentially condense and/or attach to particulate matter. The HFPO-DA stack emissions are sampled iso-kinetically using a modified SW-846 Method 0010 sampling train as previously described.

The Modified Method 0010 sampling train was operated for 180 minutes during each sampling run to sample a minimum volume of three (3) dry standard cubic meters (dscm). The stack sampling location traverse points were determined and performed in accordance with EPA Method 1. Stack velocity and flow rate were determined based on EPA Method 2 (pitot tube) measurements. Dry gas meter flow, pressure, and temperature data were used to determine the total volume of dry gas sampled. Dry gas molecular weight was determined via Method 3A analysis of the dry gas meter exhaust. Impinger moisture gain was used to determine stack gas moisture content per EPA Method 4.

2.3.5 Sample Analyses

Waste line and stack gas samples are analyzed as described in the following sections.

2.3.5.1 Waste Gas Line Analyses

The characterization of the five (5) target PFAS compounds in the waste gas feed lines was determined via analysis of the Modified Method 18 impinger contents. Please refer to Table 2-2. HFPO, HFPO-DAF, COF_2, and Fluoroether E-1 were determined using Method 8260B analysis. HFPO, HFPO-DAF, and COF_2 were quantified via analysis for their respective derivative ester compounds and reported respectively as HFPO, HFPO-DA, and COF_2 equivalents. Fluoroether E-1 was quantified via direct analysis using Method 8260B. HFPO-DA was quantified via direct analysis using EPA Method 537.

Each of the Modified Method 18 impinger samples was recovered and analyzed separately. Analysis results were then used to calculate target analyte feed rates. The sum of the positive analysis results for each target compound was used to determine the waste gas feed line concentration with zero being used for non-detect values.

2.3.5.2 Stack Gas Method 18 Analyses

The emissions of the HFPO, HFPO-DAF, COF_2, and Fluoroether E-1 were determined via analysis of the Modified Method 18 impinger contents. Please refer to Table 2-2. Like the waste gas feed lines, HFPO, HFPO-DAF, COF_2, and Fluoroether E-1 are determined using Method 8260B analysis. HFPO, HFPO-DAF, and COF_2 were quantified via analysis for their respective derivative ester compounds and reported respectively as HFPO, HFPO-DA, and COF_2 equivalents. Fluoroether E-1 was quantified via direct analysis using Method 8260B.

Each of the Modified Method 18 impinger samples was recovered and analyzed separately. In calculating target analyte emission rates, the following approach is used:

- For cases where all of the impinger analysis results are non-detect (ND) for a target analyte, the earliest (first) impinger reporting limit (RL) is used as the Modified Method 18 train total catch for that analyte.
- For cases where some, but not all of the impinger analysis results are non-detect (ND) for a target analyte, the sum of the positive analysis results and the RL of earliest or last non-detect impinger is used as the Modified Method 18 train total catch for that analyte.
- For cases where all of the impinger analysis results are positive for a target analyte, the sum of the positive analysis results is used as the Modified Method 18 train total catch for that analyte.

All stack gas Modified Method 18 analytical results for HFPO-DAF, COF_2, and Fluoroether E-1 were non-detect values. Therefore, the HFPO-DAF, COF_2, and Fluoroether E-1 emission rates were based on the methodology noted in the first bullet, above.

HFPO was detected at slightly above the RL in Impingers 1, 3, 4, and 6 of the Run 1 Modified Method 18. Therefore, the Run 1 HFPO emission rates were based on the methodology noted in the second bullet above which ends up including all seven impingers.

HFPO was not detected the Run 2 and Run 3 Modified Method 18 samples. Therefore, the Run 2 and Run 3 HFPO emission rates were based on the methodology noted in the first bullet, above.

2.3.5.3 Stack Gas Method 0010 Analyses

The seven (7) fractions from the Modified Method 0010 sampling train components were prepared using SW-846 Method 3542 and analyzed for HFPO-DA via EPA Method 537. Sampling train fractions were combined as noted below and a total of four (4) separate analyses were performed per sampling train:

- Front-half composite (probe, nozzle, and filter holder front half solvent rinses, and particulate filter)
- Back-half composite (XAD-2 resin, coil condenser and filter holder back half solvent rinses, and impinger solvent rinses)
- Condensate and impinger contents, and
- Breakthrough XAD-2 resin tube.

The sum of the first three (3) sampling train fraction analyses noted above is used for the sampling train total catch. The fourth fraction, the breakthrough XAD-2 resin tube, was analyzed to assess breakthrough and is excluded from the emissions determination calculations.

2.3.6 PFAS Feed and Stack Emission Rates

Waste gas feed line sampling and analysis data were reduced and reported as mass of HFPO, HFPO-DA, HFPO-DAF, COF_2, and Fluoroether E-1 per total mass of waste gas feed. These data and thermal oxidizer waste gas line mass flow meter data were used to determine the HFPO, HFPO-DA, HFPO-DAF, COF_2, and Fluoroether E-1 mass feed rates to the thermal oxidizer.

The Modified Method 18 sampled volume data and analysis results were used to determine the HFPO, HFPO-DAF, COF_2, and Fluoroether E-1 stack emission concentrations. The Modified Method 0010 sampled volume data and analysis results were used to determine the HFPO-DA stack emission concentration. The Modified Method 0010 stack flow data were used to determine the HFPO, HFPO-DA, HFPO-DAF, COF_2, and Fluoroether E-1 stack emission rates.

Example equations are presented in Section 4.0 of this test report.

2.3.7 Other Sampling and Analysis

In addition to the waste gas feed lines and thermal oxidizer stack emissions, the demineralized water make-up used in the scrubber system, and the HF acid and Stage 4 purge streams from the scrubber system were sampled and analyzed for the same five (5) target PFAS compounds. The purpose of the analysis of the demineralized water make-up samples was to evaluate possible target analyte contamination introduced to the stack gas scrubbing system that could impact the stack gas emissions sampling results. The purpose for the analysis of the acid and purge samples was to evaluate the possible fate of the target analytes.

Table 2-1. Properties and Structures of Target Destruction Efficiency PFAS Compounds

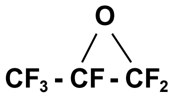
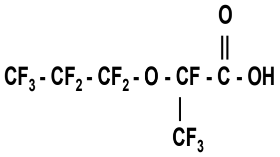
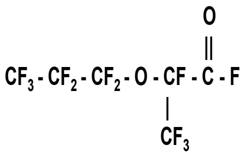
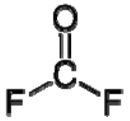
Compound	Hexafluoropropylene oxide	Hexafluoropropylene Dimer Acid or C_3-Dimer	Hexafluoropropylene Dimer Acid Fluoride	Carbonyl Difluoride	Heptafluoropropyl-1,2,2,2-tetrafluoroethyl ether
Acronym	HFPO	HFPO-DA	HFPO-DAF	COF_2	Fluoroether E-1
CAS No.	428-59-1	13252-13-6	2062-98-8	353-50-4	3330-15-2
Molecular Formula	C_3F_6O	$C_6HF_{11}O_3$	$C_6F_{12}O_2$	COF_2	$C_5HF_{11}O$
Mole Weight	166.02	330.05	332.04	66.01	286.04
Molecular Structure		 $CF_3-CF_2-CF_2-O-\underset{CF_3}{\underset{\mid}{CF}}-\overset{O}{\overset{\|}{C}}-OH$	 $CF_3-CF_2-CF_2-O-\underset{CF_3}{\underset{\mid}{CF}}-\overset{O}{\overset{\|}{C}}-F$		CF3-CF2-CF2-O-CF–F3
Normal B.P., °C @ 760 mmHg	-28	151	56	-85	40
V.P. @ 25°C, psia	98.7 (Gas)	0.0224	0.551	Gas	8.1
V.P. @ 25°C, mmHg abs	5,103 (Gas)	1.16	28.5	Gas	419
Note	Reacts with methanol to form methyl-2-methoxy-tetrafluoro-propionate (2-MTP), B.P. 41°C.	None	Reacts with methanol to form HFPO dimer, methyl ester ($HFPO-DOCH_3$), B.P. 116°C.	Reacts with methanol to form dimethyl carbonate (DMC), B.P. 90°C.	Thermal decarboxylation product of HFPO-DA

Table 2-2. Analysis and Reporting Convention for Test Samples

Target Analyte	Derivative Compound or Target Analyte Actually Measured in the Laboratory	Analytical Method	Reported Equivalent Compound
HFPO Monomer CAS #428-59-1	Methyl 2-methoxytetrafluoropropionate (2-MTP) CAS #10186-63-7	SW-846 Method 8260	HFPO Monomer CAS #428-59-1
HFPO-DAF CAS #2062-98-8	HFPO, Dimer Methyl Ester CAS #13140-34-6	SW-846 Method 8260	HFPO-DAF CAS #2062-98-8
Carbonyl Difluoride CAS #353-50-4	Dimethyl Carbonate CAS #616-38-6	SW-846 Method 8260	Carbonyl Difluoride CAS #353-50-4
Fluoroether E-1 CAS #3330-15-2	Fluoroether E-1 CAS #3330-15-2	SW-846 Method 8260	Fluoroether E-1 CAS #3330-15-2
HFPO-DA (C_3-Dimer) CAS #13252-13-6	HFPO-DA (C_3-Dimer) CAS #13252-13-6	EPA Method 537	HFPO-DA (C_3-Dimer) CAS #13252-13-6

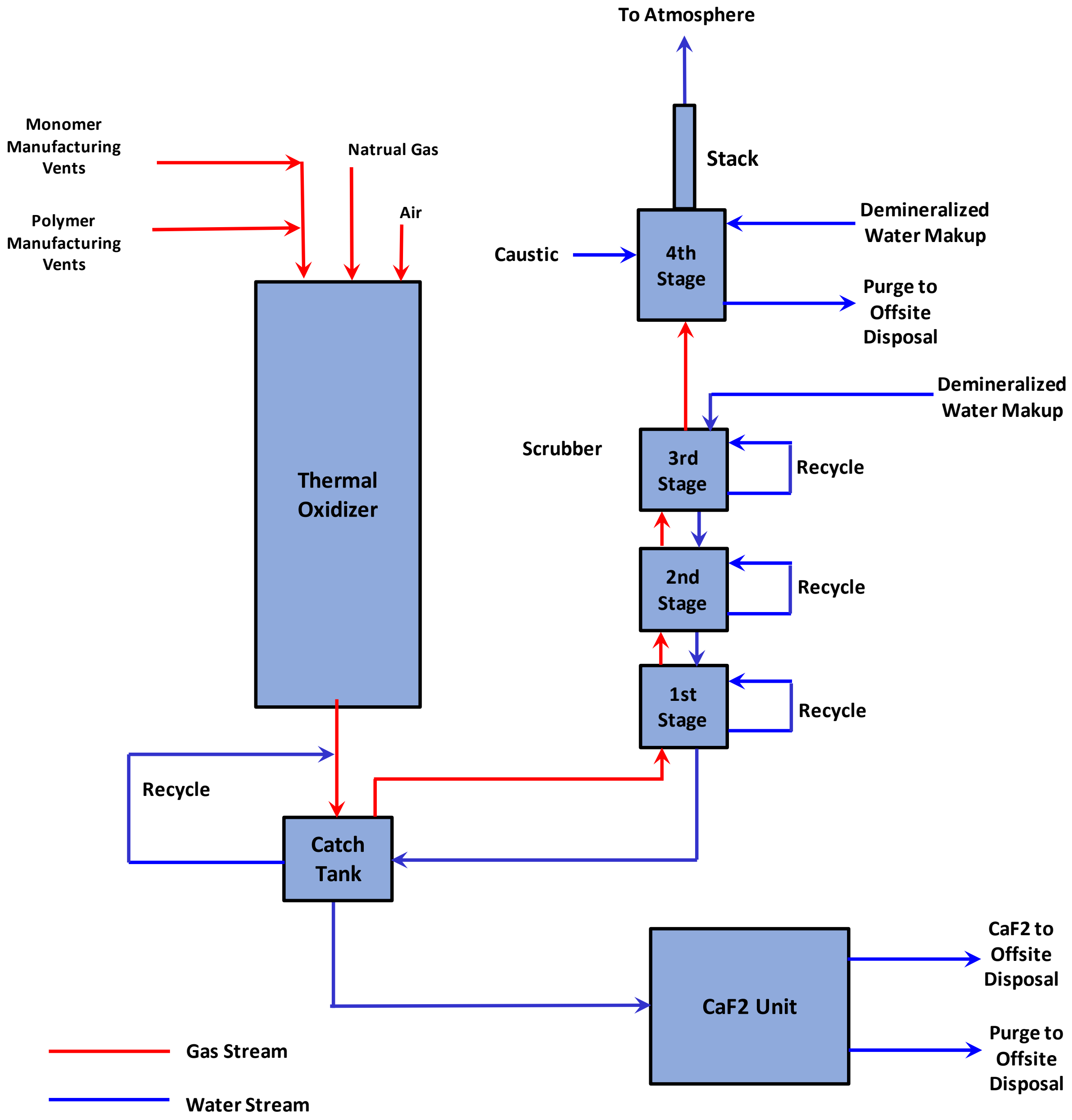
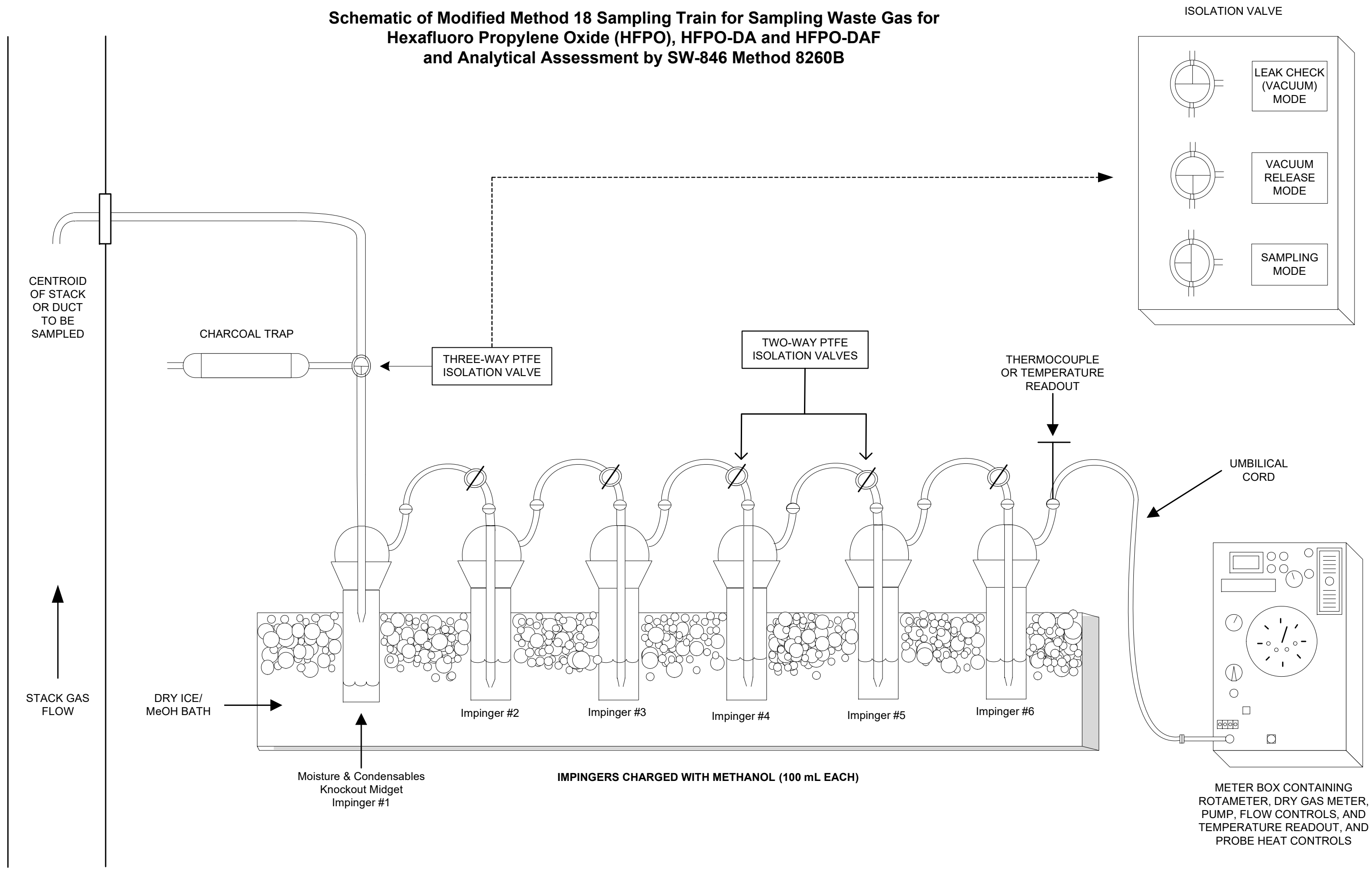
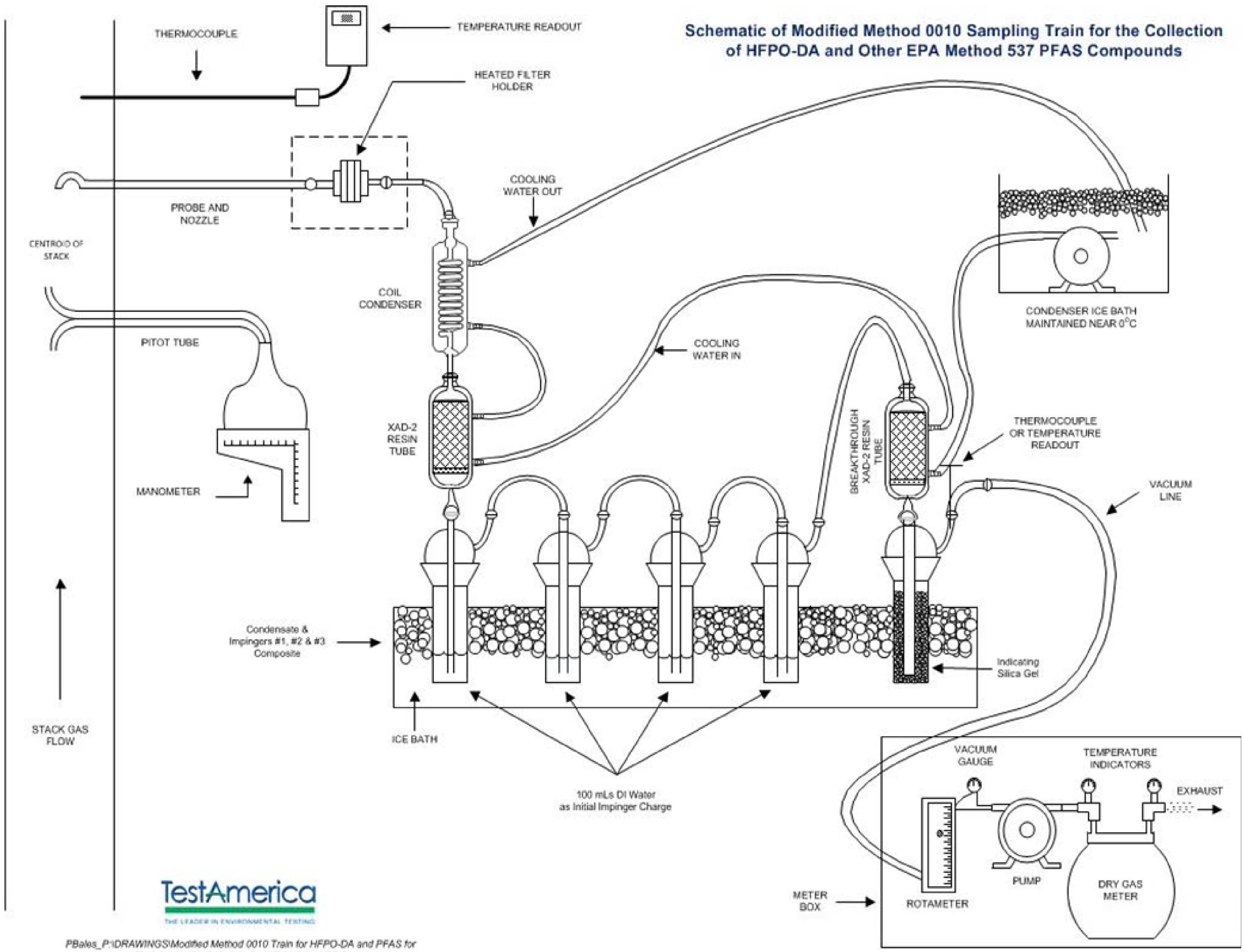


Figure 2-1. Thermal Oxidizer Process Flow Schematic


Schematic of Modified Method 18 Sampling Train for Sampling Waste Gas for Hexafluoro Propylene Oxide (HFPO), HFPO-DA and HFPO-DAF and Analytical Assessment by SW-846 Method 8260B

P:\1_PBB Project Files\Chemours_102017\Handout for Raleigh NC Meeting on December 6 2019\Modified Method 18 Train Schematic for Chemours_3 Compounds_FINAL_112719.vsd
Created by Patti Bales_Last Edited on 3/17/2020 12:40 PM

Figure 2-2. Modified Method 18 Sampling Train Schematic



Schematic of Modified Method 0010 Sampling Train for the Collection of HFPO-DA and Other EPA Method 537 PFAS Compounds

PBales_P:\DRAWINGS\Modified Method 0010 Train for HFPO-DA and PFAS for Procedures_011819.vsd Last Edited 1/18/2019

Figure 2-3. Modified Method 0010 Sampling Train Schematic

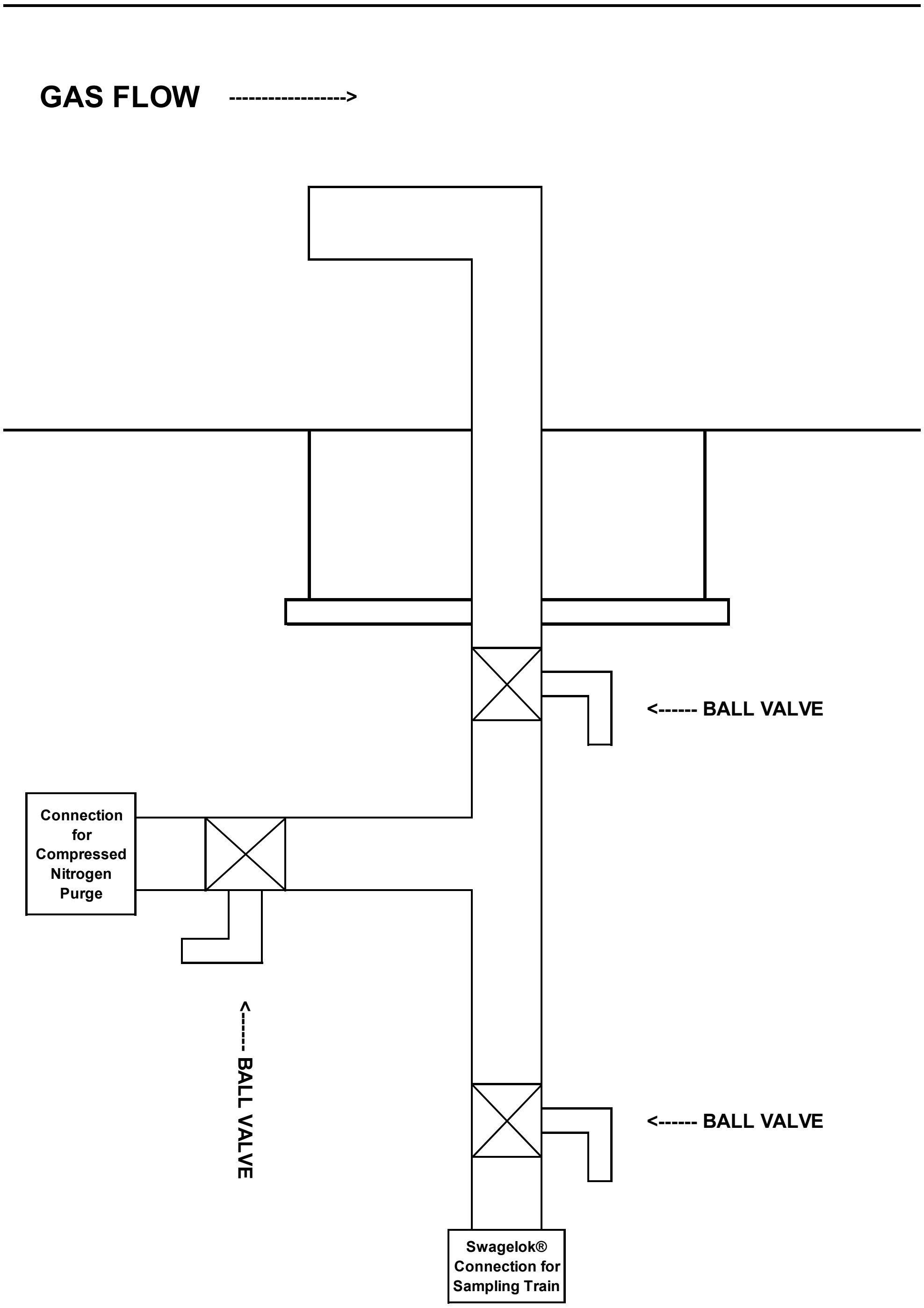


Figure 2-4. Installed Waste Gas Sampling Point Schematic

3.0 TEST PROGRAM SUMMARY

3.1 PERFORMANCE OBJECTIVE

The thermal oxidizer test performance objective was to demonstrate 99.99% DE of PFAS compounds. The test program was designed to characterize and determine the inlet feed rates, and the stack emissions rates of five (5) site-specific target compounds: HFPO, HFPO-DA, HFPO-DAF, COF_2, and Fluoroether E-1. The development details of the sampling and analysis methodologies used are presented in the preceding Section 2.0. System DE performance was calculated based on the sum of the system inlet feed rates, and sum of the stack emissions rates of these five (5) compounds.

3.2 TEST IMPLEMENTATION SUMMARY

Table 3-1 summarizes the test program sampling and analysis. The thermal oxidizer test program was conducted January 26-28, 2021. Three (3) runs of waste gas feed line sampling and thermal oxidizer emissions sampling were performed. Table 3-2 summarizes the sampling dates and times. The performance test was conducted in substantial conformance with the approved test plan.

3.3 TEST OPERATING OBJECTIVES

The thermal oxidizer operating conditions are summarized in Table 3-3. The one-minute operating data are included as Appendix A of the Ramboll report.

3.4 DEVIATIONS FROM THE TEST PLAN

Three deviations from the approved test plan are noted:

- Sampling and analysis for a fifth compound, Fluoroether E-1, was added to the sampling and analysis scope. This addition to the test program expanded the amount of target PFAS compounds potentially characterized in the waste gas feed and emissions for DE performance determination.

- Sampling of the Stage 1 scrubber purge stream was deleted from the test program. Sampling of this stream was primarily included in the test plan as an option to sampling of the HF acid stream. Sampling of either stream provides similar process information. Deletion of the Stage 1 scrubber purge stream sampling had no impact on test results or determinations.

- An additional (7th) impinger was added to the stack gas Modified Method 18 sampling train serving primarily as a moisture knockout trap. This impinger was charged with methanol, and placed in-series as the 1st impinger, preceding the other six (6) impingers described in Section 2.3.3.1. This added 7th impinger was not chilled with dry ice as the other six (6) were, but was maintained in a separate regular ice water bath at approximately 2˚C to knock out moisture vapor while avoiding the freezing of condensed water from the stack gas. Condensed moisture from the stack gas would potentially freeze in the 1st methanol/dry ice bath impinger or connecting tubing possibly plugging up the sampling train. This additional impinger was recovered, analyzed and reported as a separate sample.

Table 3-1. Thermal Oxidizer Performance Test Sampling and Analysis

Sample Name	Sampling Location/ Access	Sampling Equipment	Sampling Reference Method [1]	Sample Size/Frequency-	Target Analyte(s)	Analytical Reference Method [2]
Monomer Waste Gas Feed Line #1	Specially fabricated sampling port	Modified Method 18 Sampling Train	EPA Method 18	0.5-1.0 liters per minute concurrent with Method 0010 stack gas sampling	HFPO-DAF, HFPO, COF_2, & Fluoroether E-1 HFPO-DA	SW8-46 Method 8260B (Reaction Products) EPA Method 537 [2]
Polymer Waste Gas Feed Line #2	Specially fabricated sampling port	Modified Method 18 Sampling Train	EPA Method 18	0.5-1.0 liters per minute concurrent with Method 0010 stack gas sampling	HFPO-DAF, HFPO, COF_2, & Fluoroether E-1 HFPO-DA	SW-846 Method 8260B (Reaction Products) EPA Method 537 [2]
Stack Gas	Stack Port	Modified Method 18 Sampling Train	EPA Method 18	~2.0 liters per minute concurrent with Method 0010 stack gas sampling	HFPO, HFPO-DAF, COF_2, & Fluoroether E-1	SW-846 Method 8260B (Reaction Products)
Stack Gas	Isokinetic Port	Modified Method 0010 Sampling Train	SW-846 Method 0010	Minimum sampled volume of 3.0 dry standard cubic meters [3,4]	HFPO-DA	EPA Method 537 [2]
Demineralized Makeup Water	Tap on line	50-100 mL Plastic Graduated Cylinder; 60 and 1000 mL HDPE Sample Bottles	ASTM E-300-86	Sampling Frequency: At the start of the test run and at 60-minute intervals during each test run. Sample Size: Note 5	HFPO, HFPO-DAF, COF_2, & Fluoroether E-1 HFPO-DA	SW-846 Method 8260B (Reaction Products) EPA Method 537
HF Acid Stream	Tap on line	50-100 mL Plastic Graduated Cylinder; 60 and 1000 mL HDPE Sample Bottles	ASTM E-300-86	Same as Demineralized Water	HFPO, HFPO-DAF, COF_2, & Fluoroether E-1 HFPO-DA	SW-846 Method 8260B (Reaction Products) EPA Method 537

Table 3-1. Thermal Oxidizer Performance Test Sampling and Analysis

Sample Name	Sampling Location/ Access	Sampling Equipment	Sampling Reference Method [1]	Sample Size/Frequency-	Target Analyte(s)	Analytical Reference Method [2]
Stage 4 Purge	Tap on line	50-100 mL Plastic Graduated Cylinder; 60 mL HDPE Sample Bottles	ASTM E-300-86	Same as Demineralized Water	HFPO, HFPO-DAF, COF_2, & Fluoroether E-1 HFPO-DA	SW846 Method 8260B (Reaction Products) EPA Method 537

Notes:

[1] Reference Sampling Method Sources:

"ASTM" refers to American Society for Testing Materials, Annual Book of ASTM Standards, Annual Series
"SW-846" refers to Test Methods for Evaluating Solid Waste, Third Edition, November 1986, and Updates.
"EPA Method" refers to New Source Performance Standards, Test Methods and Procedures, Appendix A, 40 CFR 60.

[2] Reference Analysis Methods Sources:

- Modified Method 18 – "Measurement of Gaseous Organic Compound Emissions by Gas Chromatography." EPA 40 CFR Part 60, Appendix A.
- Method 0010 – "Modified Method 5 Sampling Train". Taken from Test Methods for Evaluating Solid Waste: Physical/Chemical Methods Compendium, SW-846, Third Edition, September 1986 and its updates, USEPA, OSWER, Washington, D.C. 20460.
- Method 5, Appendix A, Test Methods and Procedures, New Source Performance Standards, 40 CFR 60.
- Method 8260B – "Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)". Taken from Test Methods for Evaluating Solid Waste: Physical/Chemical Methods Compendium, SW-846, Third Edition, September 1986 and its updates, USEPA, OSWER, Washington, D.C. 20460.
- Method 3542A – "Extraction of Semivolatile Analytes Collected Using Method 0010 ("Modified Method 5 Sampling Train")". Taken from Test Methods for Evaluating Solid Waste: Physical/Chemical Methods Compendium, SW-846, Third Edition, September 1986 and its updates, USEPA, OSWER, Washington, D.C. 20460.
- Method 537 – "Determination of Selected Perfluorinated Alkyl Acids In Drinking Water By Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)", Version 1.1, September 2009, EPA/600/R-08/092.

Table 3-1. Thermal Oxidizer Performance Test Sampling and Analysis

[3] The exact volume of gas sampled will depend on the isokinetic sampling rate.

[4] Isokinetic sampling trains include:

- Sampling traverse points determined in accordance with EPA Method 1.
- Performing stack gas velocity, pressure and temperature profile measurement for each sampling location (EPA Method 2)
- Oxygen and carbon dioxide concentrations measured to determine stack gas molecular weight (EPA Method 3A)
- Determining the moisture content of the stack gas for each sampling train sample (EPA Method 4).

[5] Two sample portions of these process streams are collected at each sampling interval:

- For samples receiving the HFPO, HFPO-DAF, COF_2, and Fluoroether E-1 analyses, a graduated cylinder was used to measure a 40 mL aliquot of the collected material and transfer it to a 60 mL HDPE bottle containing methanol. The lid was placed on the sample bottle and sealed. The methanol reacts with HFPO, HFPO-DAF, and COF_2 under these conditions to form derivative products that are evaluated by the laboratory. . The grab portions of these samples were composited in the laboratory to provide a single representative result for each test run.
- For the HFPO-DA analysis sample, a 100 ml aliquot of the collected material was placed into a 1000 ml HDPE bottle. The lid was placed on the sample bottle and sealed. Each additional aliquot was added to the bottle to build a field composite of the process sample. The laboratory analyzed the composited sample to provide a single representative result for each test run.

The different sample portions are labeled to distinguish between those receiving analysis for the HFPO, HFPO-DAF, COF_2, and Fluoroether E-1, and those receiving analysis for HFPO-DA. The final number of discrete sample aliquot portions collected was dependent on the final run duration.

Table 3-2. Thermal Oxidizer Performance Test Sampling Dates and Times

Run No.:	Run 1	Run 2	Run 3
Date:	26-Jan-21	27-Jan-21	28-Jan-21
Start:	11:15	09:00	08:40
Finish:	14:31	12:11	11:58
Duration:	3:16	3:11	3:18

Table 3-3. Thermal Oxidizer Destruction Efficiency Test Operating Data

Parameter	Units	Permit	Statistic	Run 1	Run 2	Run 3	Average
Monomer Waste Gas	lb/hr	NA	Average	429.3	430.6	448.9	436.3
			Maximum	502.5	506.7	569.3	526.2
			Minimum	376.6	374.3	343.6	364.8
			Std Dev	33.9	32.1	56.9	41.0
Polymer Waste Gas	lb/hr	NA	Average	186.4	184.5	191.3	187.4
			Maximum	192.0	188.0	195.5	191.8
			Minimum	177.9	180.0	186.8	181.6
			Std Dev	2.8	1.7	1.9	2.1
Total Waste Gas	lb/hr	<2,500	Average	615.8	615.0	640.2	623.7
			Maximum	689.1	689.5	758.2	712.3
			Minimum	564.8	557.3	536.0	552.7
			Std Dev	33.3	32.1	57.2	40.8
Combustion Temperature	deg F	>1,800	Average	2,012	2,013	2,012	2,012
			Maximum	2,015	2,015	2,015	2,015
			Minimum	2,008	2,010	2,007	2,009
			Std Dev	1	1	2	2
Scrubber Flow Rate	gpm	>40	Average	88.2	88.2	88.2	88.2
			Maximum	88.8	88.7	88.6	88.7
			Minimum	87.8	87.7	87.7	87.7
			Std Dev	0.2	0.2	0.2	0.2
Scrubber pH	SU	>7.1	Average	8.17	7.94	7.99	8.04
			Maximum	8.20	7.97	8.11	8.09
			Minimum	8.13	7.92	7.92	7.99
			Std Dev	0.02	0.01	0.05	0.03

4.0 TEST RESULTS

4.1 TEST DATA REDUCTION BASIS

The strategy for the determination of the PFAS target analyte feed rates and their emissions evaluation are conducted to provide the most conservative assessment of the thermal oxidizer performance. Specifically:

- Calculation of PFAS target analyte feed rates use zero (0) for laboratory non-detect (ND) values determined from the waste gas line Modified Method 18 sampling and analyses. No feed rate credit or contribution is taken for constituents below the sampling and analysis measurement limits.
- The stack gas ND values represent the quantitative limits of the sampling and analytical measurements under the test conditions. Actual emissions are not assumed to be zero (0), but are assigned the reporting limit (RL) value for the method. The Modified Method 18 sampling train includes seven (7) impingers in-series that are recovered and analyzed separately. The calculation of PFAS Modified Method 18 measured stack emission rates is based on the RL for the first in-series impinger when all seven (7) impingers are ND for a target analyte. For any impingers with positive results for a specific analyte, the detected value is used and summed with the RL for any preceding impingers in-series and the RL of the last ND impinger in-series for the analyte.
- The Modified Method M0010 measured stack emission rates are based on separate analysis of three (3) sampling train fractions [front-half composite (FH), back-half composite (BH), and the combined impinger contents and rinses composite]. During this test program, HFPO-DA was detected in all three (3) sampling fractions during all three (3) sampling runs. Therefore, the calculation of HFPO-DA Modified Method 0010 measured stack emission rates is based on the sum of all three (3) analysis fraction detected values. The breakthrough XAD-2 resin analyses serve as quality control (QC) indicators and are excluded from the HFPO-DA emissions determinations.

The balance of Section 4.0 details how the test data were reduced to determine thermal oxidizer PFAS DE performance.

4.2 WASTE GAS CHARACTERIZATION AND TARGET PFAS COMPOUND FEED RATES

The waste gas feed lines were sampled using the Modified Method 18 sampling train. Tables 4-1 and 4-2 summarize the analyses of the polymer and monomer waste gas feed lines. Tables 4-3 and 4-4 summarize the feed rates of the target PFAS compounds. The detailed waste gas feed line sampling data are included in Source Emissions Testing of a Thermal Oxidizer and Scrubber System Stack, The Chemours Company – Fayetteville, North Carolina, Ramboll, March 2021 included as an attachment to this test report. Please note that a zero "0" was applied for calculations used for sample fractions that were reported by the laboratory as non-detect (ND).

The waste gas feed rates to the thermal oxidizer are measured by mass flow meters. To determine the target compound feed rates, the waste gas feed sampling and analysis data were reduced to yield mass of target compound per total mass feed.

Please refer to Tables 4-1 and 4-2. Each of the waste gas feed line sampling train fraction mass concentrations for a target analyte were added together to provide the total mass of each target compound during a test run. The compound mass totals were determined from sum of the individual impinger analyses:

$$C_{TOTi} = \sum C_{Ni}$$

Where: C_{TOTi} = Total mass of individual target compound for a test run,

C_{Ni} = Individual mass results of each target compound.

The total mass of all target PFAS compounds captured during a test run was determined from the sum of the individual target PFAS compounds:

$$C_{PFAS} = \sum C_{TOTi}$$

Where: C_{PFAS} = Total mass of target PFAS compounds

C_{TOTi} = Total mass of each target compound.

Please refer to Tables 4-3 and 4-4. From the Modified Method 18 sampling train recovery data, the total mass of waste gas vapors condensed was determined from the sum of the changes in the impinger masses:

$$\Delta IM_{TOT} = \sum \Delta IM_N$$

Where: ΔIM_{TOT} = Total impinger mass change

ΔIM_N = Individual impinger mass changes.

From the Modified Method 18 sampling train dry gas metering system data, the mass of dry gas sampled was determined:

$$DG_M = V_M * DGMC * (T_S/T_M) * [(P_B)/(P_S)] * MW_G/MV_{STP}$$

Where: DG_M = Dry gas mass

V_M = Dry gas meter measured volume

DGMC = Dry gas meter coefficient

T_S = Standard temperature in °R or °K

T_M = Dry gas meter temperature in °R or °K

P_B = Barometric pressure

P_S = Standard pressure

MW_G = Dry gas molecular weight

MV = Molar volume (volume per mole of gas at STP)

STP = Standard temperature and pressure.

Tables 4-3 and 4-4 show the reduced sampled volumes from the previously referenced Ramboll report for the waste gas feed line Modified Method 18 sampling trains in dry standard liters. The waste gas feed line dry gas fraction was assumed to be 100% nitrogen and was assigned a molecular weight of 28 amu. The mass of dry gas sampled was determined by multiplying the measured dry gas standard sample volume by the molecular weight of nitrogen and dividing by the molar volume at standard temperature and pressure, 24.055 liter/gram mole. The total mass sampled from the waste gas feed line is the sum of dry gas total mass and the impinger mass gain:

$$M_{TOT} = DG_M + \Delta IM_{TOT}$$

Where: M_{TOT} = Total organic vapor and dry gas mass sampled

ΔIM_{TOT} = Total impinger mass change

DG_M = Dry gas mass.

The mass fraction of the target PFAS compounds per total mass feed was determined dividing total mass of target PFAS compounds captured by the total mass sampled:

$$FC_{PFAS} = C_{PFAS}/M_{TOT}$$

Where: FC_{PFAS} = Feed concentration of target PFAS compounds in mass/total mass sampled

C_{PFAS} = Total mass of target compound

M_{TOT} = Total mass of organic vapor and dry gas mass sampled.

The total PFAS target compound mass feed rate was determined by multiplying the calculated mass fraction of total PFAS target compounds by the mass feed rate measured by the thermal oxidizer mass flow meters:

$$FR_{PFAS} = FC_{CPFAS} * MF$$

Where: FR_{PFAS} = Mass feed rate of target compound

FC_{CPFAS} = Feed concentration of target compound in mass/total mass

MF = Mass feed rate measured by the mass flow meter.

4.3 TARGET PFAS COMPOUND STACK EMISSION RATES

Two (2) sampling trains were used to measure the stack emission rates of the target PFAS compounds:

- Modified Method 0010 for HFPO-DA, and
- Modified Method 18 for HFPO, HFPO-DAF, COF_2, and Fluoroether E-1.

The detailed stack gas sampling data and laboratory analysis reports are included in Appendixes B and C, respectively of the previously referenced Ramboll report.

4.3.1 Modified Method 0010 Measured Emissions

Please refer to Table 4-5. From the Modified Method 0010 sampling train fraction analysis, the total mass of the target compound was determined from sum of the individual fraction composite analyses:

$$C_{TOT} = C_{FH} + C_{BH} + C_{IMP}$$

Where:

C_{TOT} = Total mass of target compound

C_{FH} = Mass of target compound in front half fraction (probe, nozzle, and front half solvent rinses and particulate filter)

C_{BH} = Mass of target compound in back half fraction (XAD-2 resin, and back half and impinger solvent rinses)

C_{IMP} = Mass of target compound in impinger fraction (condensate and impinger liquid).

From the Modified Method 0010 sampling train dry gas metering system data, the volume of dry gas sampled was determined:

$$DG_V = V_M * DGMC * (T_S/T_M) * [(P_B + \Delta H)/(P_S)]$$

Where:

DG_V = Dry gas volume sampled at standard temperature and pressure

V_M = Dry gas meter measured volume

DGMC = Dry gas meter coefficient

T_S = Standard temperature in °R or °K

T_M = Dry gas meter temperature in °R or °K

P_B = Barometric pressure

ΔH = Delta H sampling pressure (vacuum)

P_S = Standard pressure.

The details of the stack gas Modified Method 0010 sampled volume determinations are included in the previously referenced Ramboll report. The sampled stack gas volumes from the Ramboll report reduced to standard conditions are presented in Table 4-5. The stack gas concentration of the HFPO-DA was determined by dividing the total mass of HFPO-DA by the sampled volume:

$$EC_C = C_{TOT}/DG_V$$

Where:

EC_C = Emission concentration of target compound in mass/dry volume

C_{TOT} = Total mass of target compound

DG_V = Dry gas volume sampled at standard temperature and pressure.

The stack flow rates from the Ramboll report reduced to standard conditions are presented in Table 4-5. The emission rate of the HFPO-DA was determined by multiplying the stack gas concentration by the stack flow rate:

$$ER_C = EC_C * SF_{DG}$$

Where:

ER_C = Emission rate of target compound

EC_C = Emission concentration of target compound in mass/dry volume

SF_{DG} = Dry gas stack flow rate at standard temperature and pressure (as determined from Method 0010 data) (Method 1, 2, 3A, and 4 data).

4.3.2 Modified Method 18 Measured Emissions

Please refer to Table 4-6. From the Modified Method 18 sampling train fraction analysis, the total mass of each target compound was determined from sum of the individual impinger analyses:

$$C_{TOT} = \sum C_N$$

Where:

C_{TOT} = Total mass of target compound

C_N = Individual impinger mass analysis results.

Analysis results for three of the four (3 of 4) target compounds measured using Modified Method 18 were non-detect (ND). As noted in Section 2.3.5.2, only the reporting limit (RL) for the first impinger was used to calculate PFAS emissions results for these three compounds. The Run 2 and Run 3 Modified Method 18 were analysis results for HFPO were also non-detect in all seven (7) impingers. For these two test runs, only the reporting limit for the first impinger was used to calculate HFPO emissions. As noted in Section 2.3.5.2, positive results for HFPO were exhibited just above the reporting limit in Impingers 1, 3, 4, and 6. Therefore, for Run 1 the positive results for these four (4) impingers and the reporting limits for Impingers 2, 5, and 7 were summed to calculate HFPO emissions for Run 1.

From the Modified Method 18 sampling train dry gas metering system data, the volume of dry gas sampled was determined:

$$DG_V = V_M * DGMC * (T_S/T_M) * [(P_B + \Delta H)/(P_S)]$$

Where: DG_V = Dry gas volume sampled at standard temperature and pressure

V_M = Dry gas meter measured volume

$DGMC$ = Dry gas meter coefficient

T_S = Standard temperature in °R or °K

T_M = Dry gas meter temperature in °R or °K

P_B = Barometric pressure

ΔH = Delta H sampling pressure (vacuum)

P_S = Standard pressure.

P_S = Standard pressure.

The details of the stack gas Modified Method 18 sampled volume determinations are included in the previously referenced Ramboll report. The sampled stack gas volumes from the Ramboll report reduced to standard conditions are presented in Table 4-6. The stack gas concentration of target compounds was determined by dividing the total mass of the target compounds by the sampled volume:

$$EC_C = C_{TOT}/DG_V$$

Where: EC_C = Emission concentration of target compounds in mass/dry volume

C_{TOT} = Total impinger mass of target compounds

DG_V = Dry gas volume sampled at standard temperature and pressure.

Please refer to Table 4-7. The emission rate of the target compounds was determined by multiplying the stack gas concentration by the stack flow rate:

$$ER_C = EC_C * SF_{DG}$$

Where: ER_C = Emission rate of target compound

EC_C = Emission concentration of target compound in mass/dry volume

SF_{DG} = Dry gas stack flow rate at standard temperature and pressure
(as determined from Method 0010 data)
(Method 1, 2, 3A, and 4 data).

4.4 TOTAL PFAS DESTRUCTION EFFICIENCY

Please refer to Table 4-8, "Total PFAS" is the arithmetic sum of HFPO, HFPO-DA, HFPO-DAF, COF_2, and Fluoroether E-1. The total PFAS destruction efficiency (DE) was calculated by dividing the difference of the total PFAS feed rate and the total PFAS emission rate by the total PFAS feed rate:

$$DE = (FR-ER)/FR * 100\%$$

Where:

DE = Total PFAS destruction efficiency, percent (%)

FR = Total PFAS mass feed rate

ER = Total PFAS mass emission rate.

The total PFAS DE performance results presented in Table 4-8 demonstrate that the thermal oxidizer controls all PFAS at an efficiency greater than 99.99%.

Table 4-1. Thermal Oxidizer Monomer Tank Feed (Line #1) Summary Analyses

Target Compound	Train Fraction	Units	Run 1	Run 2	Run 3
COF2	Impinger 1	ug	47,900,000	49,000,000	52,900,000
COF2	Impinger 2	ug	2,480,000	1,060,000	3,100,000
COF2	Impinger 3	ug	103,000	124,000	176,000
COF2	Impinger 4	ug	5,910	6,640	12,500
COF2	Impinger 5	ug	ND	ND	ND
COF2	Impinger 6	ug	ND	ND	ND
COF2	**Total**	**ug**	**50,488,910**	**50,190,640**	**56,188,500**
HFPO-DAF	Impinger 1	ug	ND	ND	ND
HFPO-DAF	Impinger 2	ug	ND	ND	ND
HFPO-DAF	Impinger 3	ug	ND	ND	ND
HFPO-DAF	Impinger 4	ug	ND	ND	ND
HFPO-DAF	Impinger 5	ug	ND	ND	ND
HFPO-DAF	Impinger 6	ug	ND	ND	ND
HFPO-DAF	**Total**	**ug**	**0**	**0**	**0**
HFPO	Impinger 1	ug	207,000	84,000	277,000
HFPO	Impinger 2	ug	334,000	126,000	401,000
HFPO	Impinger 3	ug	340,000	232,000	292,000
HFPO	Impinger 4	ug	266,000	197,000	366,000
HFPO	Impinger 5	ug	220,000	162,000	263,000
HFPO	Impinger 6	ug	174,000	111,000	170,000
HFPO	**Total**	**ug**	**1,541,000**	**912,000**	**1,769,000**
Fluoroether E-1	Impinger 1	ug	ND	ND	ND
Fluoroether E-1	Impinger 2	ug	ND	ND	ND
Fluoroether E-1	Impinger 3	ug	ND	ND	ND
Fluoroether E-1	Impinger 4	ug	ND	ND	ND
Fluoroether E-1	Impinger 5	ug	ND	ND	ND
Fluoroether E-1	Impinger 6	ug	ND	ND	ND
Fluoroether E-1	**Total**	**ug**	**0**	**0**	**0**
HFPO-DA	Impinger 1	ug	1,730,000	2,560,000	2,360,000
HFPO-DA	Impinger 2	ug	292,000	131,000	407,000
HFPO-DA	Impinger 3	ug	18,300	50,900	36,900
HFPO-DA	Impinger 4	ug	6,040	18,100	13,100
HFPO-DA	Impinger 5	ug	2,520	5,960	6,330
HFPO-DA	Impinger 6	ug	1,320	2,430	2,760
HFPO-DA	**Total**	**ug**	**2,050,180**	**2,768,390**	**2,826,090**
Total Target PFAS Mass		**grams**	**54.08**	**53.87**	**60.78**

Table 4-2. Thermal Oxidizer Polymer Tank Feed (Line #2) Summary Analyses

Target Compound	Train Fraction	Units	Run 1	Run 2	Run 3
COF2	Impinger 1	ug	600	161	1,140
COF2	Impinger 2	ug	ND	ND	ND
COF2	Impinger 3	ug	ND	ND	ND
COF2	Impinger 4	ug	ND	ND	ND
COF2	Impinger 5	ug	ND	ND	ND
COF2	Impinger 6	ug	ND	ND	ND
COF2	**Total**	**ug**	**600**	**161**	**1,140**
HFPO-DAF	Impinger 1	ug	74.9	83.6	120
HFPO-DAF	Impinger 2	ug	22.8	41.5	74.2
HFPO-DAF	Impinger 3	ug	13.2	ND	40.3
HFPO-DAF	Impinger 4	ug	ND	ND	13.2
HFPO-DAF	Impinger 5	ug	ND	ND	ND
HFPO-DAF	Impinger 6	ug	ND	ND	ND
HFPO-DAF	**Total**	**ug**	**111**	**125**	**248**
HFPO	Impinger 1	ug	ND	ND	ND
HFPO	Impinger 2	ug	ND	ND	ND
HFPO	Impinger 3	ug	ND	ND	ND
HFPO	Impinger 4	ug	ND	ND	ND
HFPO	Impinger 5	ug	ND	ND	ND
HFPO	Impinger 6	ug	ND	ND	ND
HFPO	**Total**	**ug**	**0**	**0**	**0**
Fluoroether E-1	Impinger 1	ug	468	499	1,350
Fluoroether E-1	Impinger 2	ug	40.8	38.8	127
Fluoroether E-1	Impinger 3	ug	5.56	ND	23.0
Fluoroether E-1	Impinger 4	ug	ND	ND	ND
Fluoroether E-1	Impinger 5	ug	ND	ND	ND
Fluoroether E-1	Impinger 6	ug	ND	ND	ND
Fluoroether E-1	**Total**	**ug**	**514**	**538**	**1,500**
HFPO-DA	Impinger 1	ug	50,200	76,900	109,000
HFPO-DA	Impinger 2	ug	15,300	32,900	57,900
HFPO-DA	Impinger 3	ug	10,600	3,940	25,600
HFPO-DA	Impinger 4	ug	3,840	273	8,540
HFPO-DA	Impinger 5	ug	827	50.3	1,560
HFPO-DA	Impinger 6	ug	154	ND	202
HFPO-DA	**Total**	**ug**	**80,921**	**114,063**	**202,802**
Total Target PFAS Mass		**grams**	**0.08215**	**0.1149**	**0.2057**

Table 4-3. Thermal Oxidizer Monomer Tank (Line #1) Sampling Results and Feed Rates

Parameter	Units	Run 1	Run 2	Run 3
Net Inlet Condensed Mass	grams	117.4	71.0	126.8
Speciated Compounds in Condensed Mass				
Total COF2	ug	50,488,910	50,190,640	56,188,500
Total HFPO-DAF	ug	0	0	0
Total HFPO	ug	1,541,000	912,000	1,769,000
Total Fluoroether E-1	ug	0	0	0
Total HFPO-DA	ug	2,050,180	2,768,390	2,826,090
Target PFAS Sample Mass	grams	54.08	53.87	60.78
Total Dry Gas and Condensed Mass Sampled				
Sampled Dry Gas Volume (@ 20ºC, 1 atm)	Liters	119.383	115.393	125.456
Sampled Dry Gas Mass (24.055 L/gmol, MW=28)	grams	138.962	134.317	146.031
Total Mass Sampled (Condensed + Dry Gas)	grams	256.362	205.317	272.831
Constituent Concentrations in Total Sampled Mass				
Total COF2	g/g flow	2.0E-01	2.4E-01	2.1E-01
Total HFPO-DAF	g/g flow	0.0E+00	0.0E+00	0.0E+00
Total HFPO	g/g flow	6.0E-03	4.4E-03	6.5E-03
Total Fluoroether E-1	g/g flow	0.0E+00	0.0E+00	0.0E+00
Total HFPO-DA	g/g flow	8.0E-03	1.3E-02	1.0E-02
Total Target PFAS Characterized	g/g flow	2.1E-01	2.6E-01	2.2E-01
Calculated Constituent Feed Rates				
Monomer Tank Gas Flow (estimate)	lb/hr	429.3	430.6	448.9
Monomer Tank Gas Flow	kg/hr	194.7	195.3	203.6
Total COF2	g/hr	38,354	47,743	41,933
Total HFPO-DAF	g/hr	0	0	0
Total HFPO	g/hr	1,171	868	1,320
Total Fluoroether E-1	g/hr	0	0	0
Total HFPO-DA	g/hr	1,557.40	2,633.38	2,109.08
Total Target PFAS Feed	**g/hr**	**41,082**	**51,244**	**45,362**

Table 4-4. Thermal Oxidizer Polymer Tank (Line # 2) Sampling Results and Feed Rates

Parameter	Units	Run 1	Run 2	Run 3
Net Inlet Condensed Mass	grams	-29.6	-2.4	0.6
Speciated Compounds in Condensed Mass				
Total COF2	ug	600	161	1,140
Total HFPO-DAF	ug	111	125	248
Total HFPO	ug	0	0	0
Total Fluoroether E-1	ug	514	538	1,500
Total HFPO-DA	ug	80,921	114,063	202,802
Target PFAS Sample Mass	grams	0.08215	0.11489	0.20569
Total Dry Gas and Condensed Mass Sampled				
Sampled Dry Gas Volume (@ 20°C, 1 atm)	Liters	120.866	116.382	126.021
Sampled Dry Gas Mass (24.055 L/gmol, MW=28)	grams	140.688	135.468	146.689
Total Mass Sampled (Condensed + Dry Gas)	grams	111.088	133.068	147.289
Constituent Concentrations in Total Sampled Mass				
Total COF2	g/g flow	5.4E-06	1.2E-06	7.7E-06
Total HFPO-DAF	g/g flow	1.0E-06	9.4E-07	1.7E-06
Total HFPO	g/g flow	0.0E+00	0.0E+00	0.0E+00
Total Fluoroether E-1	g/g flow	4.6E-06	4.0E-06	1.0E-05
Total HFPO-DA	g/g flow	7.3E-04	8.6E-04	1.4E-03
Total Target PFAS Characterized	g/g flow	7.4E-04	8.6E-04	1.4E-03
Calculated Constituent Feed Rates				
Polymer Tank Gas Flow	lb/hr	186.4	184.5	191.3
Polymer Tank Gas Flow	kg/hr	84.6	83.7	86.8
Total COF2	g/hr	0.457	0.101	0.672
Total HFPO-DAF	g/hr	0.084	0.0787	0.146
Total HFPO	g/hr	0.000	0.000	0.000
Total Fluoroether E-1	g/hr	0.392	0.338	0.884
Total HFPO-DA	g/hr	61.6	71.7	119.5
Total Target PFAS Feed	**g/hr**	**62.5**	**72.2**	**121.2**

Table 4-5. Thermal Oxidizer Modified Method 0010 Emissions Results

Parameter	Units	Run 1	Run 2	Run 3
Stack Flow	dscfm	5,894	6,044	6,058
Method 0010 Sampled Volume	dscf	158.722	164.908	171.554
Method 0010 Front Half HFPO-DA	ug	0.0739	0.280	0.180
Method 0010 Back Half HFPO-DA	ug	0.0246	0.429	0.249
Method 0010 Impingers HFPO-DA	ug	0.0583	0.0888	0.0972
Method 0010 Breakthrough XAD HFPO-DA (Breakthrough Indicator Only)	ug	0.00920	0.0164	0.00717
Method 0010 Train Total HFPO-DA (Excludes Breakthrough XAD)	ug	0.157	0.798	0.526
Method 0010 HFPO-DA Emissions	g/hr	0.000349	0.00175	0.00111

Table 4-6. Thermal Oxidizer Stack Modified Method 18 Sample Analyses

Parameter	Units	Run 1	Run 2	Run 3
Speciated Compounds in Impingers				
COF2, Impinger 1	ug	< 4.07	< 2.06	< 2.12
COF2, Impinger 2	ug	< 2.32	< 2.70	< 2.10
COF2, Impinger 3	ug	< 2.37	< 2.24	< 2.24
COF2, Impinger 4	ug	< 2.04	< 2.40	< 2.02
COF2, Impinger 5	ug	< 2.42	< 2.32	< 1.98
COF2, Impinger 6	ug	< 2.54	< 2.58	< 2.10
COF2, Impinger 7	ug	< 2.08	< 2.48	< 2.31
Total COF2 including ND Values	**ug**	**< 17.8**	**< 16.8**	**< 14.9**
Total COF2 only Impinger 1	**ug**	**< 4.07**	**< 2.06**	**< 2.12**
Total COF2 only Impinger 1 or Positive Results	**ug**	**< 4.07**	**< 2.06**	**< 2.12**
HFPO-DAF, Impinger 1	ug	< 1.34	< 0.679	< 0.698
HFPO-DAF, Impinger 2	ug	< 0.764	< 0.890	< 0.690
HFPO-DAF, Impinger 3	ug	< 0.779	< 0.738	< 0.739
HFPO-DAF, Impinger 4	ug	< 0.670	< 0.788	< 0.663
HFPO-DAF, Impinger 5	ug	< 0.797	< 0.762	< 0.652
HFPO-DAF, Impinger 6	ug	< 0.837	< 0.849	< 0.692
HFPO-DAF, Impinger 7	ug	< 0.685	< 0.818	< 0.760
Total HFPO-DAF including ND Values	**ug**	**< 5.872**	**< 5.524**	**< 4.894**
Total HFPO-DAF only Impinger 1	**ug**	**< 1.340**	**< 0.679**	**< 0.698**
Total HFPO-DAF only Impinger 1 or Positive Results	**ug**	**< 1.340**	**< 0.679**	**< 0.698**
HFPO, Impinger 1	ug	0.0794	< 0.0307	< 0.0315
HFPO, Impinger 2	ug	< 0.0346	< 0.0403	< 0.0313
HFPO, Impinger 3	ug	0.0495	< 0.0334	< 0.0335
HFPO, Impinger 4	ug	0.0328	< 0.0357	< 0.0300
HFPO, Impinger 5	ug	< 0.0361	< 0.0345	< 0.0295
HFPO, Impinger 6	ug	0.0415	< 0.0384	< 0.0314
HFPO, Impinger 7	ug	< 0.0310	< 0.0370	< 0.0344
Total HFPO including ND Values	**ug**	**< 0.305**	**< 0.2500**	**< 0.2216**
Total HFPO only Impinger 1	**ug**	**NA**	**< 0.0307**	**< 0.0315**
Total HFPO only Impinger 1 or Positive Results	**ug**	**0.203**	**< 0.0307**	**< 0.0315**
Fluoroether E-1, Impinger 1	ug	< 0.0694	< 0.0352	< 0.0361
Fluoroether E-1, Impinger 2	ug	< 0.0396	< 0.0461	< 0.0358
Fluoroether E-1, Impinger 3	ug	< 0.0404	< 0.0382	< 0.0383
Fluoroether E-1, Impinger 4	ug	< 0.0347	< 0.0409	< 0.0343
Fluoroether E-1, Impinger 5	ug	< 0.0413	< 0.0395	< 0.0338
Fluoroether E-1, Impinger 6	ug	< 0.0434	< 0.0440	< 0.0359
Fluoroether E-1, Impinger 7	ug	< 0.0355	< 0.0424	< 0.0394
Total Fluoroether E-1 including ND Values	**ug**	**< 0.304**	**< 0.286**	**< 0.254**
Total Fluoroether E-1 only Impinger 1	**ug**	**< 0.0694**	**< 0.0352**	**< 0.0361**
Total Fluoroether E-1 only Impinger 1 or Positive Results	**ug**	**< 0.0694**	**< 0.0352**	**< 0.0361**
Total Characterized Including NDs	**ug**	**< 24.3**	**< 22.8**	**< 20.2**
Total Characterized only Impinger 1	**ug**	**NA**	**< 2.80**	**< 2.89**
Total Characterized only Impinger 1 or Positive Results	**ug**	**< 5.68**	**< 2.80**	**< 2.89**

Table 4-7. Thermal Oxidizer Modified Method 18 Stack Emissions Results

Parameter	Units	Run 1	Run 2	Run 3
Sampled Stack Volume	dsl	217.086	219.769	223.830
Sampled Stack Volume	dscf	6.148	6.224	6.339
Stack Flow	dscfm	5,894	6,044	6,058
Total Target PFAS only Impinger 1 or Positive Results	ug	< 5.68	< 2.80	< 2.89
Total Characterized only Impinger 1 or Positive Results	**g/hr**	**< 0.3269**	**< 0.1634**	**< 0.1655**

Table 4-8. Thermal Oxidizer Total PFAS Destruction Efficiency

Parameter	Units	Run 1	Run 2	Run 3
Monomer Feed Total Target PFAS Inlet by Modified Method 18 (ND=0)	g/hr	41,082	51,244	45,362
Polymer Feed Total Target PFAS Inlet by Modified Method 18 (ND=0)	g/hr	63	72	121
Total Target PFAS Inlet by Modified Method 18 (ND=0)	g/hr	41,144	51,316	45,483
Outlet HFPO-DA by Modified Method 0010	g/hr	0.000349	0.00175	0.00111
Outlet Other Target PFAS by Modified Method 18	g/hr	< 0.327	< 0.163	< 0.165
Total Target PFAS Outlet	**g/hr**	**< 0.327**	**< 0.165**	**< 0.167**
Total Target PFAS DE	**%**	**> 99.99920%**	**> 99.99968%**	**> 99.99963%**
Average Target PFAS DE	**%**	**> 99.99951%**		

5.0 QUALITY CONTROL

5.1 WASTE GAS SAMPLING

The waste gas constituents and their concentrations vary based on the product(s) being manufactured at any particular time. Waste gas sampling was performed using the Modified Method 18 sampling train that was developed for the Chemours Fayetteville Works test program. Both waste gas feed lines were sampled independently to determine the concentrations of the five (5) target PFAS compounds. The waste gas sampling was performed at a constant sampling rate from the start of stack gas sampling and through completion of the stack gas sampling. The samples obtained represent the average composition during each test run. The sampling and analysis data were reduced to yield mass of target analyte per total mass of waste gas in each feed line. This information and the respective waste gas feed line mass feed rate data were used to determine inlet feed rates of the target PFAS compounds. The following sections examine the quality of the waste gas feed characterization results and their associated impacts on the measurement of the thermal oxidizer DE performance.

5.1.1 Monomer Waste Gas Sampling

During the test, Vinyl Ethers North (VEN) was producing PSEPVE. COF_2, HFPO, and HFPO-DA were present in the monomer waste gas feed (Line #1), while no HFPO-DAF or Fluoroether E-1 were measured in these samples. Figures 5-1, 5-2, and 5-3 graphically show the relative loadings of each of the three (3) detected target compounds in the six (6) Modified Method 18 impingers.

COF_2 and HFPO-DA are primarily captured in the first two impingers. COF_2 readily reacts with methanol. During all three (3) runs, no COF_2 is detected after the fourth impinger. The capture of HFPO-DA is assumed to occur via condensation and dissolution, and HFPO-DA does not react with methanol. The distribution of HFPO-DA was detected in all six (6) impingers with >99% of the train total being captured in Impingers 1-3. These data show COF_2 and HFPO-DA are being captured with a high degree of efficiency.

HFPO was detected in all six (6) impingers distributed at comparable levels throughout. Capture of HFPO is dependent on both condensation and chemical reaction. These data show HFPO is being detected at a lesser degree of efficiency, thus its measured concentration and actual feed rate is higher than is being measured. A low bias to this concentration translates to a low bias in the DE determination. Therefore, a higher concentration determined for HFPO for this feed line would result in a higher DE demonstration. Despite a low bias in feed rate measurement, all PFAS DE is demonstrated to exceed 99.99% efficiency.

5.1.2 Polymer Waste Gas Sampling

During the test, Polymers was running a 920 SR polymer campaign. HFPO-DAF, COF_2, Fluoroether E-1, and HFPO-DA were present in the polymer waste gas feed (Line #2), but no HFPO was detected. Figures 5-4, 5-5, 5-6, and 5-7 graphically show the relative loadings of each of the four (4) detected target compounds in the six (6) Modified Method 18 impingers.

Except for Run 3, HFPO-DAF was detected in the first three (3) impingers with >90% of the train total being captured in Impingers 1-3; about 10% of the Run 3 capture was in Impinger 4. All COF_2 is captured in the first two (2) impingers with none detected after the second impinger. HFPO-DA was detected in five of six (5 of 6) impingers during Run 1 and Run 3, and all six (6) impingers during Run 2. All Fluoroether E-1 is captured in the first three (3) impingers with none detected after the third impinger. These data show HFPO-DAF, COF_2, HFPO-DA, and Fluoroether E-1 are being captured with a high degree of efficiency.

5.2 WASTE GAS ANALYSES

Tables 5-1 through 5-4 summarize the surrogate spike compound recoveries for the waste gas analyses.

5.2.1 Monomer Waste Gas Analyses

Please refer to Table 5-1 for the monomer waste gas (Line # 1) SW-846 Method 8260B analysis surrogate spike recoveries. For the SW-846 Method 8260B (volatile organic) analyses for COF_2, HFPO, HFPO-DAF, and Fluoroether E-1, surrogate spike recoveries ranged from 87-103%. Four (4) standard surrogate spike compounds spanning the volatile range were reported. Two of the samples required dilution and re-analysis to accurately quantify the specific target analytes. The narrow range and high degree of surrogate recoveries represent a relatively high precision and accuracy with regard to the measurements of these target analytes in the high concentration waste gas samples.

Table 5-2 refers to the monomer waste gas (Line # 1) EPA Method 537 analysis isotope dilution internal standard (IDIS) spike recoveries related to the determination of HFPO-DA. The IDIS spike recoveries of the labeled HFPO-DA ($^{13}C_3$ HFPO-DA) ranged from 55-96%. All recoveries were well within the target range of 25-150%. The data are assumed to appropriately accurate, and useable for the intended purposes.

5.2.2 Polymer Waste Gas Analyses

The analysis results show the concentrations of target compounds in the polymer gas (Feed Line #2) were nominally four (4) orders of magnitude lower than in Feed Line #1. Please refer to Table 5-3 for the polymer waste gas (Line # 2) SW-846 Method 8260B analysis surrogate spike recoveries.

For the SW-846 Method 8260B (volatile organic) analyses for COF_2, COF_2, HFPO, HFPO-DAF, and Fluoroether E-1 surrogate spike recoveries ranged from 88-103%. Four (4) standard surrogate spike compounds spanning the volatile range are reported. The narrow range and high degree of surrogate recoveries represent a relatively high degree of precision and accuracy with regard to the measurements of these target analytes in the high concentration waste gas samples.

Table 5-4 displays the polymer waste gas (Line # 2) EPA Method 537 analysis IDIS spike recoveries. The IDIS spike recoveries of the isotopically-labeled HFPO-DA ($^{13}C_3$ HFPO-DA) ranged from 100-118%. The data are assumed to appropriately accurate, and useable for the intended purposes.

5.3 STACK GAS SAMPLING

Measurement of the stack gas emission rates of the five (5) target PFAS compounds involved two (2) sampling trains:

- Modified Method 18 for COF_2, HFPO, HFPO-DAF, and Fluoroether E-1, and
- Modified Method 0010 for HFPO-DA.

The Modified Method 0010 stack was performed for 180 minutes during each test run to sample a minimum of three (3) dry standard cubic meters (dscm) of stack gas. The Modified Method 18 sampling was performed concurrently. The following sections examine the quality of the thermal oxidizer stack gas emissions sampling and analysis data results, and the associated impacts on the measurement of the thermal oxidizer DE performance.

5.3.1 Stack Gas Modified Method 18 Results

Please refer to Table 5-5 for the Modified Method 18 analysis surrogate spike recoveries.

For the SW-846 Method 8260B (volatile organic) analyses for COF_2, HFPO, HFPO-DAF, and Fluoroether E-1, surrogate spike recoveries ranged from 86-108% with the target recovery being 50-150%. The stack gas Modified Method 18 samples were analyzed using selected ion monitoring (SIM) technique to reduces the detection (reporting) limits to substantially lower levels. For this reason, recoveries of only the two (2) surrogate compounds associated with the target analytes are reported. Conversely, the previously discussed waste gas line Modified Method 18 analyses were analyzed at normal Method 8260B levels with all four (4) of the standard surrogate spike compounds spanning the volatile range being reported. The narrow range and high degree of surrogate recoveries represent a relatively high degree of both precision and accuracy with regard to the measurements of these target analytes in the stack gas.

COF_2, HFPO-DAF, and Fluoroether E-1 were “non-detect” in all Modified Method 18 sample fractions. HFPO was “non-detect” in all Run 2 and Run 3 Modified Method 18 sample fractions. The Run 1 Modified Method 18 impingers exhibited detectable levels of HFPO in four of seven (4 of 7) impingers at slightly more than the reporting limits in all cases. The stack gas Modified Method 18 blank train, proof blank, and reagent blank samples were non-detect for all four target analytes including HFPO. The HFPO in the Run 1 samples is most likely from an unidentified external source during sampling train preparation or recovery. The analytical data quality indicators display sufficient accuracy of the low measurements, and indicate that the data is reliable for demonstrating that the actual DE of the measured compounds exceeds the reported 99.999%.

5.3.2 Stack Gas Modified Method 0010 Results

Please refer to Table 5-6 for the Modified Method 0010 sampling and analysis surrogate spike recoveries.

For the EPA Method 537 analyses of the Modified Method 0010 sampling train fractions, two (2) types of surrogate spikes and three (3) isotopically labeled spiking compounds were used:

- Two (2) sampling surrogates applied to the XAD-2 resin before field sampling:
  - Isotopically labeled perfluorooctanoic acid (PFOA) ($^{13}C_8$ PFOA)
  - Isotopically labeled perfluorooctanesulfonic acid (PFOS) ($^{13}C_8$ PFOS)
- One analysis IDIS, isotopically labeled HFPO ($^{13}C_3$ HFPO-DA) applied to each analytical fraction during sample preparation for analysis.

The two (2) sampling surrogate compounds applied to the primary XAD-2 resins provide a comprehensive assessment of the system's ability to capture and retain the target analyte through all the sampling and analysis processes. [Note: These sampling surrogate compounds were not applied to the breakthrough XAD-2 resins.] The analysis IDIS applied to all analytical fractions provides an assessment of the ability to recover the target analyte through the sample preparation and analysis processes. The Modified Method 0010 fractions were analyzed using high performance precision liquid chromatography/tandem mass spectrometry (HPLC/MS/MS).

The recoveries for the two sampling surrogate spike compounds for the Run 1 and Run 2 back-half samples (XAD-2 resin, and condenser and impinger solvent rinses) ranged from 100-104% for $^{13}C_8$ PFOA and 88-89% for $^{13}C_8$ PFOS. The recoveries for the Run 3 back-half sample were 31% and 20% respectively for $^{13}C_8$ PFOA and % for $^{13}C_8$ PFOS. The target range for these compounds was 50-150%. The Run 3 recoveries indicate a potential low bias for the test run.

Table 5-6 also shows recoveries for the two (2) sampling surrogate spike compounds in the impinger and breakthrough XAD-2 fractions. These surrogate compounds are not actually applied to the sample fractions noted. Analysis data for $^{13}C_8$ PFOA and $^{13}C_8$ PFOS in these post XAD-2 resin sample fractions was obtained to assess if the surrogates applied to the primary XAD-2 resins are being stripped and travel to the impingers or the second XAD-2 trap during the sample flow through the sampling train. The values are all zero (0) which demonstrate the sampling surrogate spikes are not traveling within the sampling train.

The recoveries for the IDIS surrogate spike compound ranged from 59-104% for $^{13}C_3$ HFPO-DA. The target range was 25-150%. The excellent recoveries demonstrate the ability to recover the target analyte through the sample preparation and analysis processes.

These analytical data quality indicators for the Modified Method 0010 sampling and analysis indicate that the data are sufficiently accurate for these very low-level stack gas measurements and that the data are usable for their intended purpose.

5.3.3 Positive HFPO-DA Results

All the Modified Method 0010 stack gas train fractions exhibited low level positive results for HFPO-DA. Please refer to Table 5-7. Individual fraction and sampling train total results are all less than one (1) microgram (ug). Similar HFPO-DA levels were exhibited in the blank train (BT) and proof blank (PB) analyses. The deionized water reagent blank exhibited a positive result just above the reporting limit. The methanol reagent blank and XAD-2 resin media checks were non-detect. The positive results appear to be due to background sources and have no significant impact on the DE performance determinations.

The exact source of the low-level positive HFPO-DA results is unclear. The analysis data perhaps point to possible sampling train component artifacts, or background. It is not probable that the HFPO-DA in the samples originated from thermal oxidizer emissions. The potential for HFPO-DA to pass through the combustion system as HFPO-DA is thermodynamically improbable. Fluoroether E-1 is the thermal decarboxylation product of HFPO-DA which occurs at approximately 200-250ºF. Incomplete combustion of HFPO-DA could possibly be exhibited as Fluoroether E-1. However, the Modified Method 18 samples all give non-detect results for Fluoroether E-1 which makes the survival hypothesis seem remote. Other low-level background HFPO-DA sources are considered probable.

5.4 PROCESS WATER ANALYSES

The demineralized make-up water used in the scrubber system, and the HF acid and Stage 4 purge streams from the scrubber system were sampled and analyzed for the same five (5) target PFAS compounds. The analyses are summarized in Table 5-8.

The purpose for the sampling and analyses of the demineralized make-up water samples was to evaluate possible target analyte contamination introduced to the stack gas samples. The purpose of the acid and purge samples was to evaluate the possible fate of the target analytes.

Positive results were reported for HFPO-DA in the following samples:

- Run 1 demineralized water sample just above the reporting limit
- Run 2 and Run 3 demineralized water samples both below the reporting limit
- All three HF acid samples, all below the reporting limit, and

- Run 3 Stage 4 purge below the reporting limit.

During the DE testing, the demineralized water was introducing HFPO-DA to the combustion gas scrubbing system. For the reasons stated in the preceding section, the combustion system as a source of HFPO-DA is improbable. The mass transfer of water to the combustion gas via evaporation in the scrubbing sections may have a concentrating impact in the liquid phase on any HFPO-DA introduced to the system via the demineralized water. This concentrating impact would occur primarily in the Catch Tank with the adiabatic water saturation of the combustion gas. All three HF acid samples (Catch Tank discharge) exhibited positive results for HFPO-DA. The same demineralized water source is used as makeup to scrubbing Stage 4 and is a possible source for the positive result exhibited in one of the three Stage 4 purge samples. These also data indicate possible contribution of HFPO-DA to the Method 0010 sampling train results, but with no impact on HFPO-DA or total PFAS DE determinations.

All process water analysis results were negative for the other four (4) target PFAS compounds.

5.5 OVERALL DATA QUALITY ASSESSMENT

A comprehensive review has been conducted of the thermal oxidizer performance test data quality indicators. Quality assurance and quality control (QA/QC) measurements indicate the data sets for this test project are representative of the processes from which they are derived, and that sufficient measurements have been performed to assess the overall precision and accuracy. The conclusion from this assessment is all the data are of sufficient quality to be used for their intended purposes.

Table 5-1. Monomer Waste Gas Method 8260B Analysis Surrogate Recoveries

Method 8260B Analysis Surrogate Recoveries		Run	Surrogate Recovery			
Sample	Fraction	No.	1	2	3	4
M- 1375	Monomer Feed Line, MM18, Impinger #1	1	93%	91%	98%	102%
	COF2 Exceeded Range; Re-analysis		92%	90%	99%	102%
M- 1376	Monomer Feed Line, MM18, Impinger #2	1	92%	89%	100%	102%
M- 1377	Monomer Feed Line, MM18, Impinger #3	1	92%	90%	99%	102%
M- 1378	Monomer Feed Line, MM18, Impinger #4	1	94%	90%	100%	103%
M- 1379	Monomer Feed Line, MM18, Impinger #5	1	95%	88%	99%	102%
M- 1380	Monomer Feed Line, MM18, Impinger #6	1	93%	87%	100%	102%
M- 1381	Monomer Feed Line, MM18, Impinger #1	2	93%	88%	100%	102%
M- 1382	Monomer Feed Line, MM18, Impinger #2	2	94%	92%	102%	103%
M- 1383	Monomer Feed Line, MM18, Impinger #3	2	91%	91%	101%	102%
M- 1384	Monomer Feed Line, MM18, Impinger #4	2	93%	90%	102%	103%
M- 1385	Monomer Feed Line, MM18, Impinger #5	2	91%	89%	100%	102%
M- 1386	Monomer Feed Line, MM18, Impinger #6	2	92%	89%	100%	101%
M- 1387	Monomer Feed Line, MM18, Impinger #1	3	92%	88%	100%	102%
M- 1388	Monomer Feed Line, MM18, Impinger #2	3	92%	89%	101%	101%
M- 1389	Monomer Feed Line, MM18, Impinger #3	3	91%	89%	101%	100%
M- 1390	Monomer Feed Line, MM18, Impinger #4	3	91%	89%	100%	101%
	HFPO Dilution; Re-analysis		91%	89%	101%	100%
M- 1391	Monomer Feed Line, MM18, Impinger #5	3	93%	90%	100%	101%
M- 1392	Monomer Feed Line, MM18, Impinger #6	3	90%	88%	100%	102%

No.	Surrogate	Target
1	4-Bromofluorobenzene	57% - 152%
2	1,2-Dichloroethane-d4	70% - 160%
3	Dibromofluoromethane	62% - 134%
4	Toluene-d8	71% - 139%

Table 5-2. Monomer Waste Gas Method 8321A Analysis Surrogate Recoveries

EPA Method 537 Analysis Surrogate Recoveries		Run	$^{13}C_3$ HFPO-DA
Sample	**Fraction**	**No.**	**25-150%**
M- 1375	Monomer Feed Line, MM18, Impinger #1	1	74%
M- 1376	Monomer Feed Line, MM18, Impinger #2	1	85%
M- 1377	Monomer Feed Line, MM18, Impinger #3	1	74%
M- 1378	Monomer Feed Line, MM18, Impinger #4	1	68%
M- 1379	Monomer Feed Line, MM18, Impinger #5	1	84%
M- 1380	Monomer Feed Line, MM18, Impinger #6	1	96%
M- 1381	Monomer Feed Line, MM18, Impinger #1	2	86%
M- 1382	Monomer Feed Line, MM18, Impinger #2	2	72%
M- 1383	Monomer Feed Line, MM18, Impinger #3	2	66%
M- 1384	Monomer Feed Line, MM18, Impinger #4	2	59%
M- 1385	Monomer Feed Line, MM18, Impinger #5	2	70%
M- 1386	Monomer Feed Line, MM18, Impinger #6	2	81%
M- 1387	Monomer Feed Line, MM18, Impinger #1	3	76%
M- 1388	Monomer Feed Line, MM18, Impinger #2	3	80%
M- 1389	Monomer Feed Line, MM18, Impinger #3	3	64%
M- 1390	Monomer Feed Line, MM18, Impinger #4	3	55%
M- 1391	Monomer Feed Line, MM18, Impinger #5	3	60%
M- 1392	Monomer Feed Line, MM18, Impinger #6	3	72%

Table 5-3. Polymer Waste Gas Method 8260B Analysis Surrogate Recoveries

Method 8260B Analysis Surrogate Recoveries		Run	Surrogate Recovery			
Sample	Fraction	No.	1	2	3	4
G- 1777	Polymer Feed Line, MM18, Impinger #1	1	94%	91%	100%	101%
G- 1778	Polymer Feed Line, MM18, Impinger #2	1	93%	92%	100%	101%
G- 1779	Polymer Feed Line, MM18, Impinger #3	1	92%	90%	99%	102%
G- 1780	Polymer Feed Line, MM18, Impinger #4	1	93%	88%	98%	103%
G- 1781	Polymer Feed Line, MM18, Impinger #5	1	90%	89%	98%	101%
G- 1782	Polymer Feed Line, MM18, Impinger #6	1	89%	89%	100%	103%
G- 1783	Polymer Feed Line, MM18, Impinger #1	2	91%	88%	99%	102%
G- 1784	Polymer Feed Line, MM18, Impinger #2	2	92%	89%	101%	103%
G- 1785	Polymer Feed Line, MM18, Impinger #3	2	91%	89%	99%	102%
G- 1786	Polymer Feed Line, MM18, Impinger #4	2	89%	89%	100%	102%
G- 1787	Polymer Feed Line, MM18, Impinger #5	2	91%	90%	101%	103%
G- 1788	Polymer Feed Line, MM18, Impinger #6	2	90%	88%	100%	102%
G- 1789	Polymer Feed Line, MM18, Impinger #1	3	90%	88%	100%	102%
G- 1790	Polymer Feed Line, MM18, Impinger #2	3	89%	89%	100%	102%
G- 1791	Polymer Feed Line, MM18, Impinger #3	3	90%	88%	100%	103%
G- 1792	Polymer Feed Line, MM18, Impinger #4	3	92%	88%	96%	102%
G- 1793	Polymer Feed Line, MM18, Impinger #5	3	91%	89%	100%	102%
G- 1794	Polymer Feed Line, MM18, Impinger #6	3	90%	88%	98%	102%

No.	Surrogate	Target
1	4-Bromofluorobenzene	57% - 152%
2	1,2-Dichloroethane-d4	70% - 160%
3	Dibromofluoromethane	62% - 134%
4	Toluene-d8	71% - 139%

Table 5-4. Polymer Waste Gas Method 8321A Analysis Surrogate Recoveries

EPA Method 537 Analysis Surrogate Recoveries		Run No.	$^{13}C_3$ HFPO-DA
Sample	Fraction		25-150%
G- 1777	Polymer Feed Line, MM18, Impinger #1	1	118%
G- 1778	Polymer Feed Line, MM18, Impinger #2	1	109%
G- 1779	Polymer Feed Line, MM18, Impinger #3	1	102%
G- 1780	Polymer Feed Line, MM18, Impinger #4	1	100%
G- 1781	Polymer Feed Line, MM18, Impinger #5	1	104%
G- 1782	Polymer Feed Line, MM18, Impinger #6	1	106%
G- 1783	Polymer Feed Line, MM18, Impinger #1	2	102%
G- 1784	Polymer Feed Line, MM18, Impinger #2	2	107%
G- 1785	Polymer Feed Line, MM18, Impinger #3	2	101%
G- 1786	Polymer Feed Line, MM18, Impinger #4	2	107%
G- 1787	Polymer Feed Line, MM18, Impinger #5	2	102%
G- 1788	Polymer Feed Line, MM18, Impinger #6	2	105%
G- 1789	Polymer Feed Line, MM18, Impinger #1	3	109%
G- 1790	Polymer Feed Line, MM18, Impinger #2	3	106%
G- 1791	Polymer Feed Line, MM18, Impinger #3	3	107%
G- 1792	Polymer Feed Line, MM18, Impinger #4	3	107%
G- 1793	Polymer Feed Line, MM18, Impinger #5	3	103%
G- 1794	Polymer Feed Line, MM18, Impinger #6	3	106%

Table 5-5. Stack Gas Modified Method 18 Analysis Surrogate Recoveries

Method 8260B Analysis Surrogate Recoveries		Run	Surrogate Recovery	
Sample	Fraction	No.	1	2
QF- 1728	Stack Gas, MM18, Impinger #1	1	89%	103%
QF- 1729	Stack Gas, MM18, Impinger #2	1	91%	105%
QF- 1730	Stack Gas, MM18, Impinger #3	1	89%	106%
QF- 1731	Stack Gas, MM18, Impinger #4	1	89%	107%
QF- 1732	Stack Gas, MM18, Impinger #5	1	86%	104%
QF- 1733	Stack Gas, MM18, Impinger #6	1	88%	105%
QF- 1734	Stack Gas, MM18, Impinger #7	1	90%	107%
QF- 1735	Stack Gas, MM18, Impinger #1	2	88%	106%
QF- 1736	Stack Gas, MM18, Impinger #2	2	90%	106%
QF- 1737	Stack Gas, MM18, Impinger #3	2	94%	106%
QF- 1738	Stack Gas, MM18, Impinger #4	2	90%	106%
QF- 1739	Stack Gas, MM18, Impinger #5	2	90%	105%
QF- 1740	Stack Gas, MM18, Impinger #6	2	91%	106%
QF- 1741	Stack Gas, MM18, Impinger #7	2	88%	105%
QF- 1742	Stack Gas, MM18, Impinger #1	3	90%	108%
QF- 1743	Stack Gas, MM18, Impinger #2	3	90%	106%
QF- 1744	Stack Gas, MM18, Impinger #3	3	91%	107%
QF- 1745	Stack Gas, MM18, Impinger #4	3	90%	106%
QF- 1746	Stack Gas, MM18, Impinger #5	3	88%	106%
QF- 1747	Stack Gas, MM18, Impinger #6	3	88%	103%
QF- 1748	Stack Gas, MM18, Impinger #7	3	90%	105%

No.	Surrogate	Target
1	1,2-Dichloroethane-d4	50% - 150%
2	Dibromofluoromethane	50% - 150%

Table 5-6. Stack Gas Modified Method 0010 Analysis Surrogate Recoveries

EPA Method 537 Analysis Surrogate Recoveries		Run	Surrogate Recovery		
Sample	**Fraction**	**No.**	**1**	**2**	**3**
T- 1475 T- 1476	Stack Gas, MM0010, Front Half Composite	1	104%	NA	NA
T- 1477 T- 1478 T- 1480	Stack Gas, MM0010, Back Half Composite	1	98%	100%	89%
T- 1479	Stack Gas, MM0010, Impingers	1	101%	0%	0%
T- 1481	Stack Gas, MM0010, Breakthrough XAD	1	91%	0%	0%
T- 1482 T- 1483	Stack Gas, MM0010, Front Half Composite	2	77%	NA	NA
T- 1484 T- 1485 T- 1487	Stack Gas, MM0010, Back Half Composite	2	101%	104%	88%
T- 1486	Stack Gas, MM0010, Impingers	2	96%	0%	0%
T- 1488	Stack Gas, MM0010, Breakthrough XAD	2	77%	0%	0%
T- 1489 T- 1490	Stack Gas, MM0010, Front Half Composite	3	79%	NA	NA
T- 1491 T- 1492 T- 1494	Stack Gas, MM0010, Back Half Composite	3	59%	31%	20%
T- 1493	Stack Gas, MM0010, Impingers	3	103%	0%	0%
T- 1495	Stack Gas, MM0010, Breakthrough XAD	3	90%	0%	0%

No.	Surrogate	Target
1	$^{13}C_3$ HFPO-DA	25% - 150%
2	$^{13}C_8$ PFOA	50% - 150%
3	$^{13}C_8$ PFOS	50% - 150%

Table 5-7. Thermal Oxidizer Modified Method 0010 Analysis Results

Parameter	Units	Run 1	Run 2	Run 3	BT	PB
Method 0010 Front Half	ug	0.0739	0.280	0.180	0.123	
Method 0010 Back Half	ug	0.0246	0.429	0.249	0.3510	
Method 0010 Impingers	ug	0.0583	0.0888	0.0972	0.0340	
Total	ug	0.157	0.798	0.526	0.508	0.00257
Method 0010 Breakthrough XAD	ug	0.00920	0.0164	0.00717	0.00976	

Methanol Reagent Blank HFPO-DA	ug	<	0.00160	ND
Deionized Water Blank HFPO-DA	ug		0.00194	
XAD-2 Resin Media Check 1 HFPO-DA	ug	<	0.00160	ND
XAD-2 Resin Media Check 2 HFPO-DA	ug	<	0.00100	ND

Table 5-8. Thermal Oxidizer Process Water Analyses

Demineralized Water Analyses

Compound	Units	Run 1	Run 2	Run 3	Average
Compounds by EPA 537					
HFPO-DA	ng/L	2.68	1.07 J	1.99 J	1.91
Compounds by Method 8260B					
Carbonyl Difluoride	mg/kg	< 4.04 ND	< 4.10 ND	< 4.10 ND	< 4.08 ND
HFPO-DAF	mg/kg	< 1.28 ND	< 1.29 ND	< 1.29 ND	< 1.29 ND
HFPO	mg/kg	< 1.16 ND	< 1.17 ND	< 1.17 ND	< 1.17 ND
Fluoroether(E-1)	mg/kg	< 1.33 ND	< 1.34 ND	< 1.34 ND	< 1.34 ND

HF Acid Analyses

Compound	Units	Run 1	Run 2	Run 3	Average
Compounds by EPA 537					
HFPO-DA	ng/L	143 JH	98.6 J	153 J	132
Compounds by Method 8260B					
Carbonyl Difluoride	mg/kg	< 3.98 ND	< 3.96 ND	< 4.0 ND	< 3.98 ND
HFPO-DAF	mg/kg	< 1.25 ND	< 1.25 ND	< 1.26 ND	< 1.25 ND
HFPO	mg/kg	< 1.14 ND	< 1.14 ND	< 1.14 ND	< 1.14 ND
Fluoroether(E-1)	mg/kg	< 1.30 ND	< 1.30 ND	< 1.31 ND	< 1.30 ND

Stage 4 Purge Analyses

Compound	Units	Run 1	Run 2	Run 3	Average
Compounds by EPA 537					
HFPO-DA	ng/L	< 250 ND	< 250 ND	46.0 J	182
Compounds by Method 8260B					
Carbonyl Difluoride	mg/kg	< 3.94 ND	< 3.92 ND	< 3.94 ND	< 3.93 ND
HFPO-DAF	mg/kg	< 1.24 ND	< 1.24 ND	< 1.24 ND	< 1.24 ND
HFPO	mg/kg	< 1.13 ND	< 1.12 ND	< 1.13 ND	< 1.13 ND
Fluoroether(E-1)	mg/kg	< 1.29 ND	< 1.28 ND	< 1.29 ND	< 1.29 ND

Run No.	Impinger #1 (µg/Sample)	Percent (%) Impinger #1	Impinger #2 (µg/Sample)	Percent (%) Impinger #2	Impinger #3 (µg/Sample)	Percent (%) Impinger #3	Impinger #4 (µg/Sample)	Percent (%) Impinger #4	Impinger #5 (µg/Sample)	Percent (%) Impinger #5	Impinger #6 (µg/Sample)	Percent (%) Impinger #6	Train Total (µg)
1	47,900,000	94.9%	2,480,000	4.91%	103,000	0%	5,910	0%	0	0%	0	0%	50,488,910
2	49,000,000	97.6%	1,060,000	2.11%	124,000	0%	6,640	0%	0	0%	0	0%	50,190,640
3	52,900,000	94.1%	3,100,000	5.52%	176,000	0%	12,500	0%	0	0%	0	0%	56,188,500

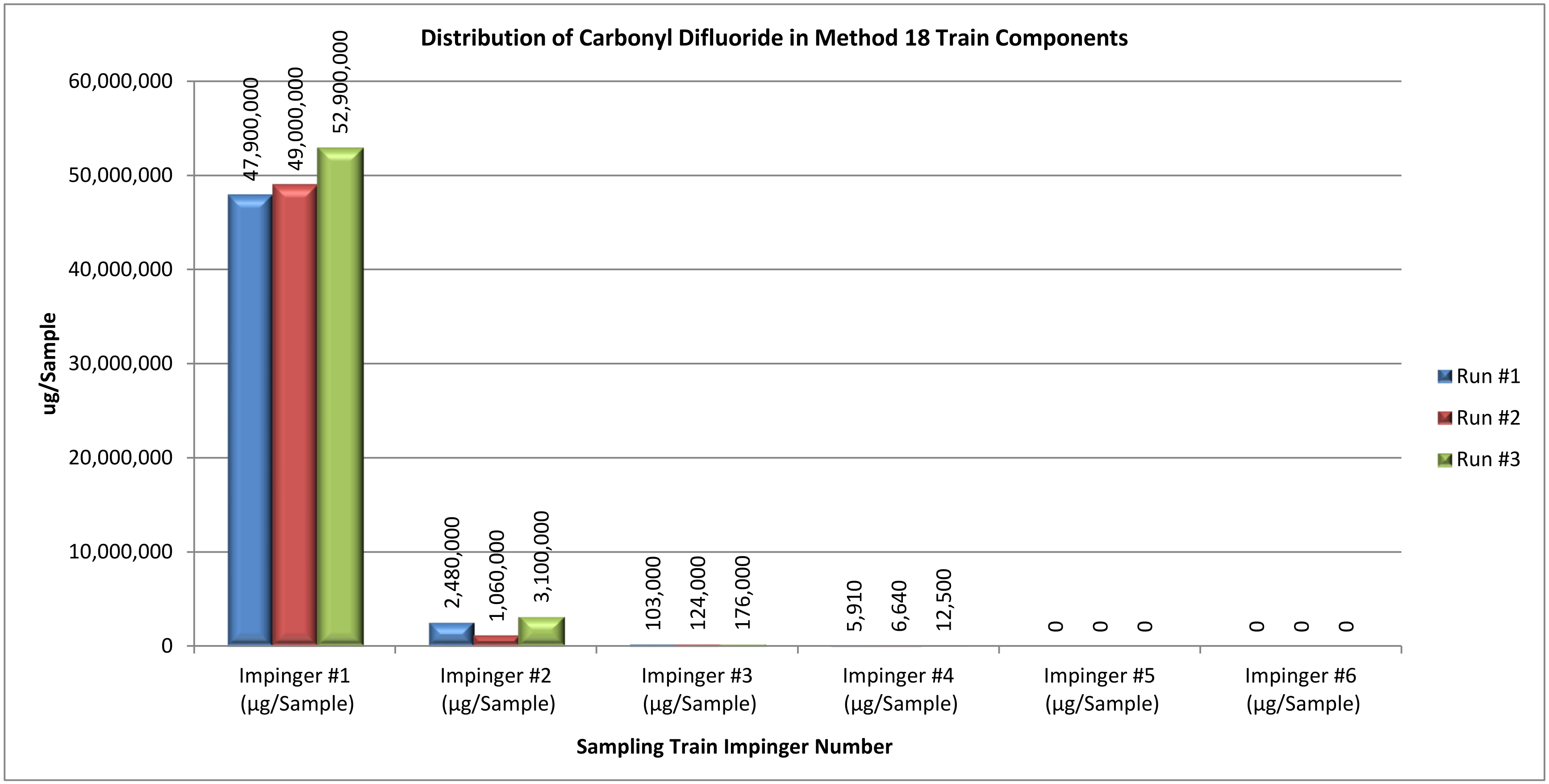


Figure 5-1. Monomer Waste Gas (Line #1) Modified Method 18 COF_2 Capture

Run No.	Impinger #1 (µg/Sample)	Percent (%) Impinger #1	Impinger #2 (µg/Sample)	Percent (%) Impinger #2	Impinger #3 (µg/Sample)	Percent (%) Impinger #3	Impinger #4 (µg/Sample)	Percent (%) Impinger #4	Impinger #5 (µg/Sample)	Percent (%) Impinger #5	Impinger #6 (µg/Sample)	Percent (%) Impinger #6	Train Total (µg)
1	207,000	13.4%	334,000	21.6%	340,000	22.0%	266,000	17.2%	222,000	14.4%	174,000	11.3%	1,543,000
2	84,000	9.21%	126,000	13.8%	232,000	25.4%	197,000	21.6%	162,000	17.8%	111,000	12.2%	912,000
3	277,000	15.66%	401,000	22.7%	292,000	16.5%	366,000	20.7%	263,000	14.9%	170,000	9.6%	1,769,000

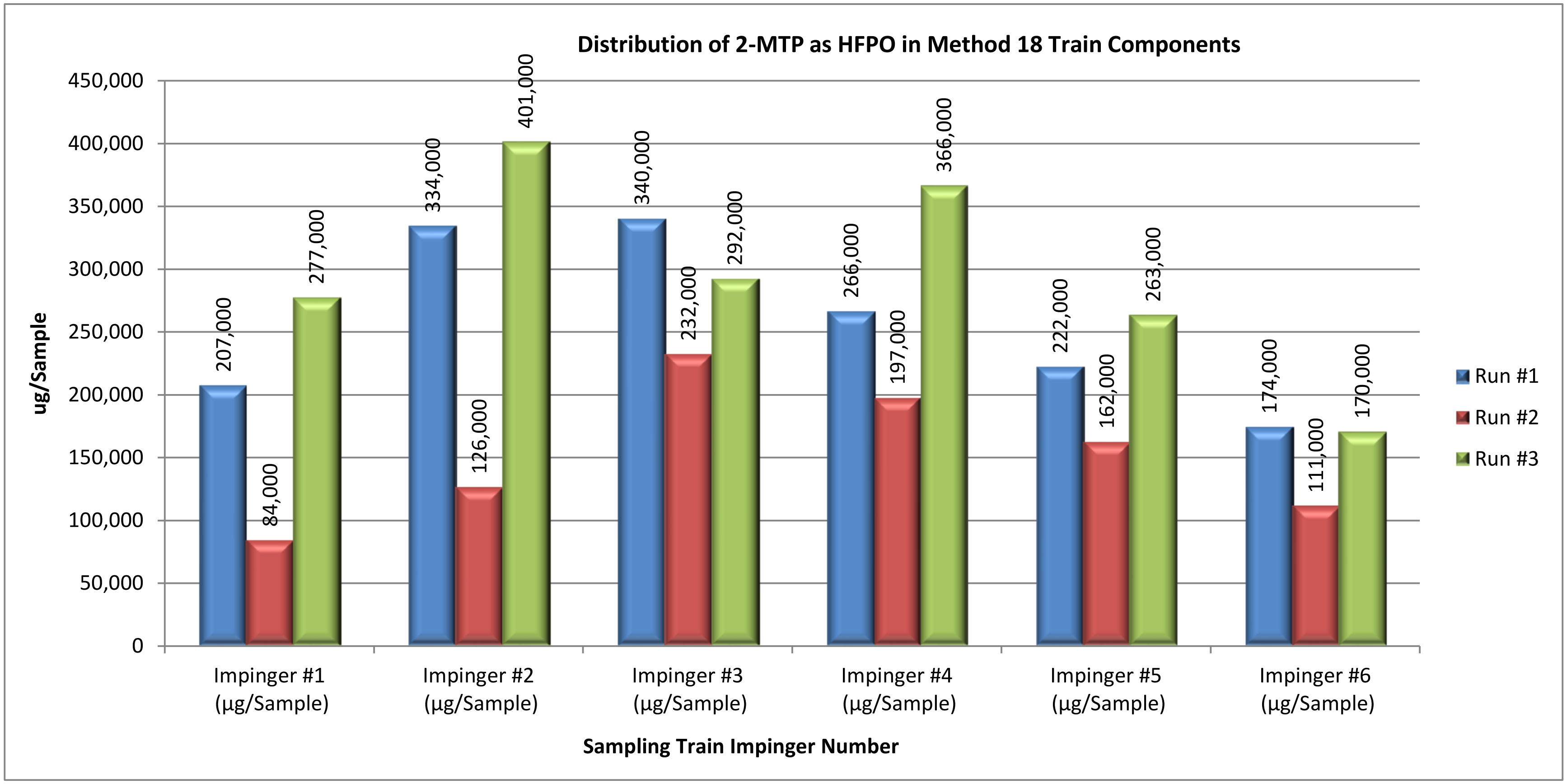


Figure 5-2. Monomer Waste Gas (Line #1) Modified Method 18 HFPO Capture

Run No.	Impinger #1 (µg/Sample)	Percent (%) Impinger #1	Impinger #2 (µg/Sample)	Percent (%) Impinger #2	Impinger #3 (µg/Sample)	Percent (%) Impinger #3	Impinger #4 (µg/Sample)	Percent (%) Impinger #4	Impinger #5 (µg/Sample)	Percent (%) Impinger #5	Impinger #6 (µg/Sample)	Percent (%) Impinger #6	Train Total (µg)
1	1,730,000	84.4%	292,000	14.2%	18,300	0.893%	6,040	0.295%	2520	0.123%	1320	0.0644%	2,050,180
2	2,560,000	92.5%	131,000	4.73%	50,900	1.84%	18,100	0.654%	5960	0.215%	2430	0.0878%	2,768,390
3	2,360,000	83.5%	407,000	14.4%	36,900	1.31%	13,100	0.464%	6330	0.224%	2760	0.0977%	2,826,090

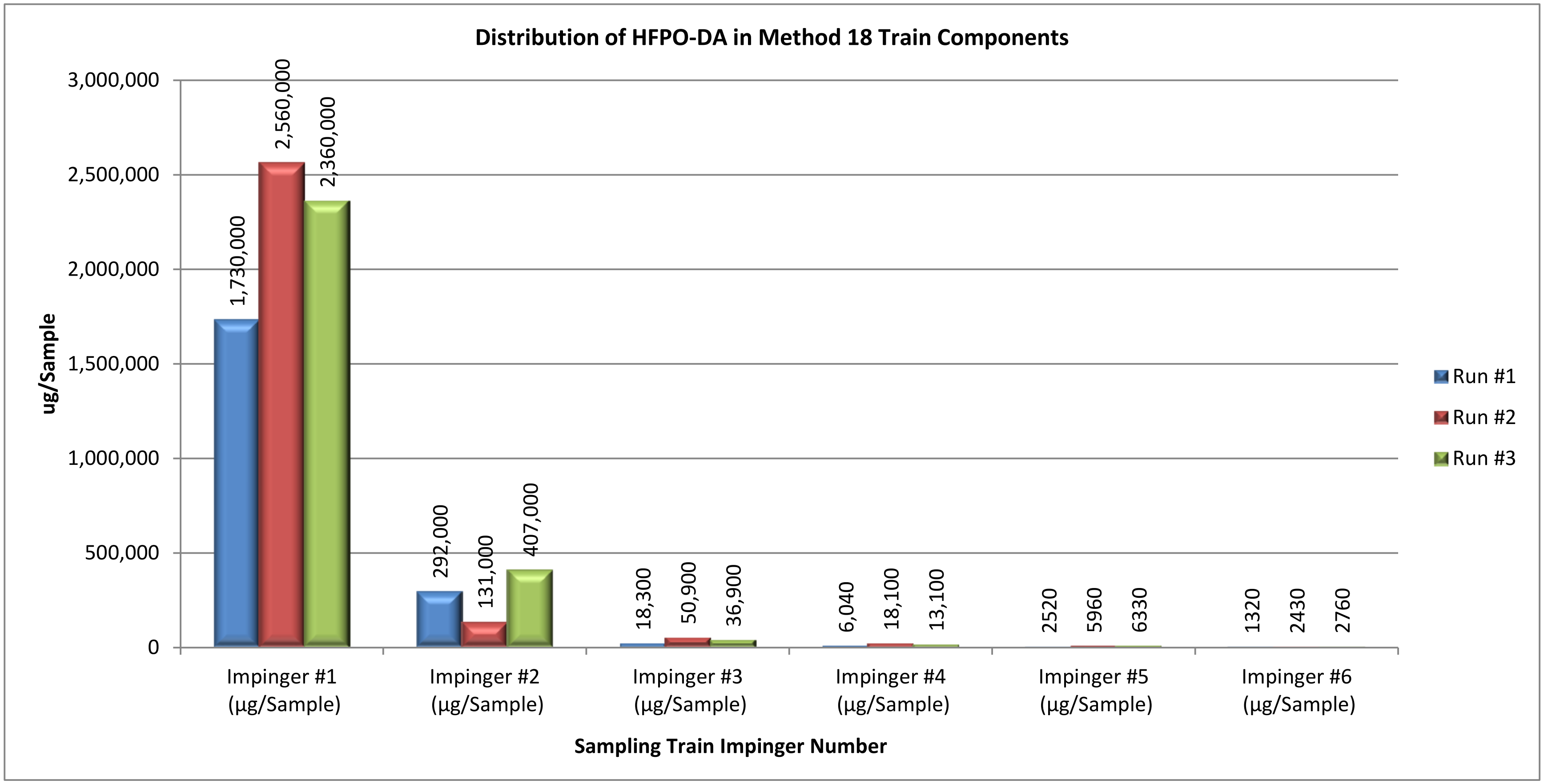


Figure 5-3. Monomer Waste Gas (Line #1) Modified Method 18 HFPO-DA Capture

Run No.	Impinger #1 (µg/Sample)	Percent (%) Impinger #1	Impinger #2 (µg/Sample)	Percent (%) Impinger #2	Impinger #3 (µg/Sample)	Percent (%) Impinger #3	Impinger #4 (µg/Sample)	Percent (%) Impinger #4	Impinger #5 (µg/Sample)	Percent (%) Impinger #5	Impinger #6 (µg/Sample)	Percent (%) Impinger #6	Train Total (µg)
1	74.9	0%	22.8	0%	13.2	0%	0	0%	0	0%	0	0%	111
2	83.6	0%	41.5	0%	0	0%	0	0%	0	0%	0	0%	125
3	120	0%	74.2	0%	40.3	0%	13.2	0%	0	0%	0	0%	248

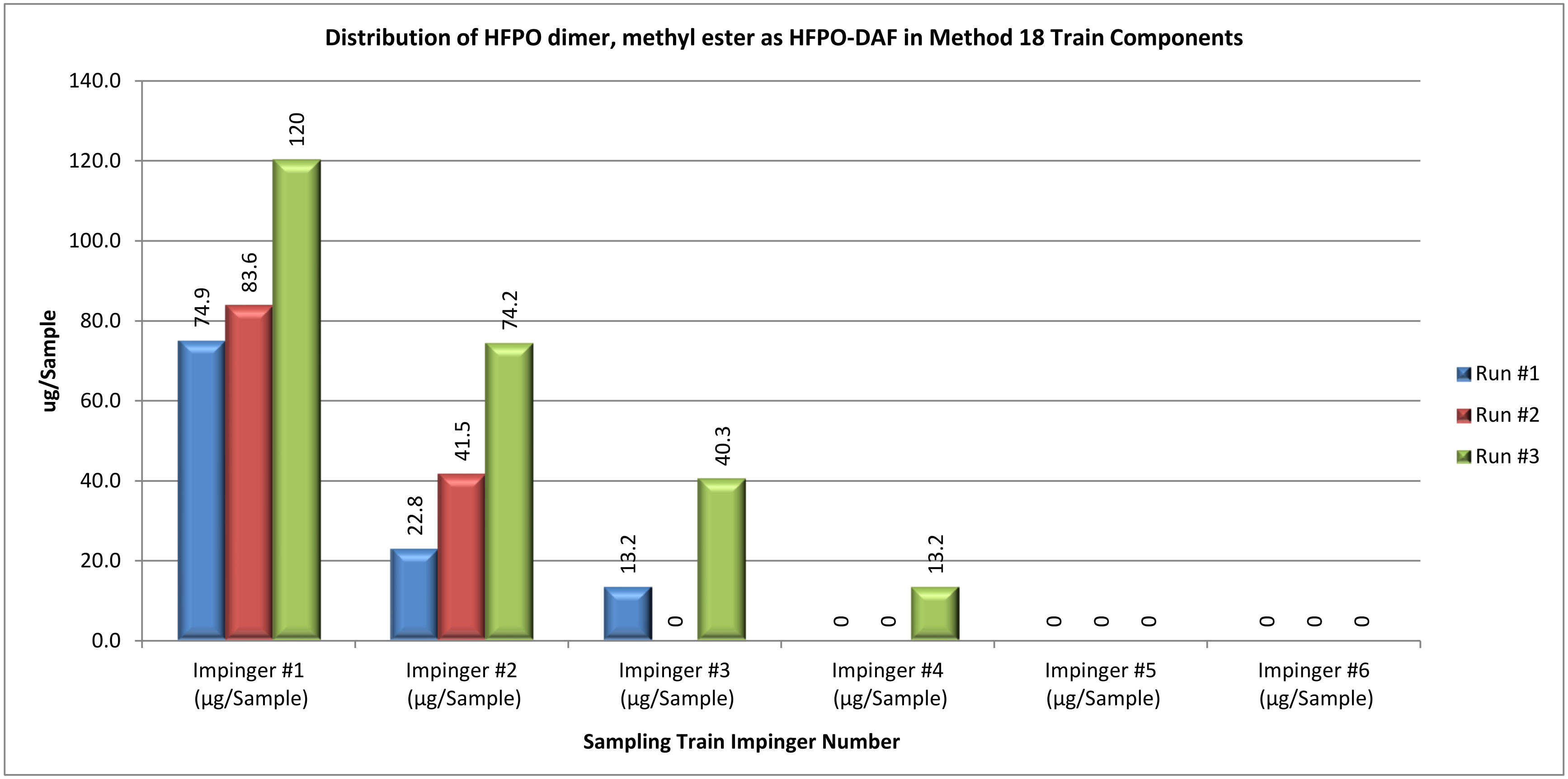


Figure 5-4. Polymer Waste Gas (Line #2) Modified Method 18 HFPO-DAF Capture

Run No.	Impinger #1 (µg/Sample)	Percent (%) Impinger #1	Impinger #2 (µg/Sample)	Percent (%) Impinger #2	Impinger #3 (µg/Sample)	Percent (%) Impinger #3	Impinger #4 (µg/Sample)	Percent (%) Impinger #4	Impinger #5 (µg/Sample)	Percent (%) Impinger #5	Impinger #6 (µg/Sample)	Percent (%) Impinger #6	Train Total (µg)
1	600	100.0%	0	0.00%	0	0%	0	0%	0	0%	0	0%	600
2	161	100.0%	0	0.00%	0	0%	0	0%	0	0%	0	0%	161
3	1,140	96.0%	48.1	4.05%	0	0%	0	0%	0	0%	0	0%	1,188

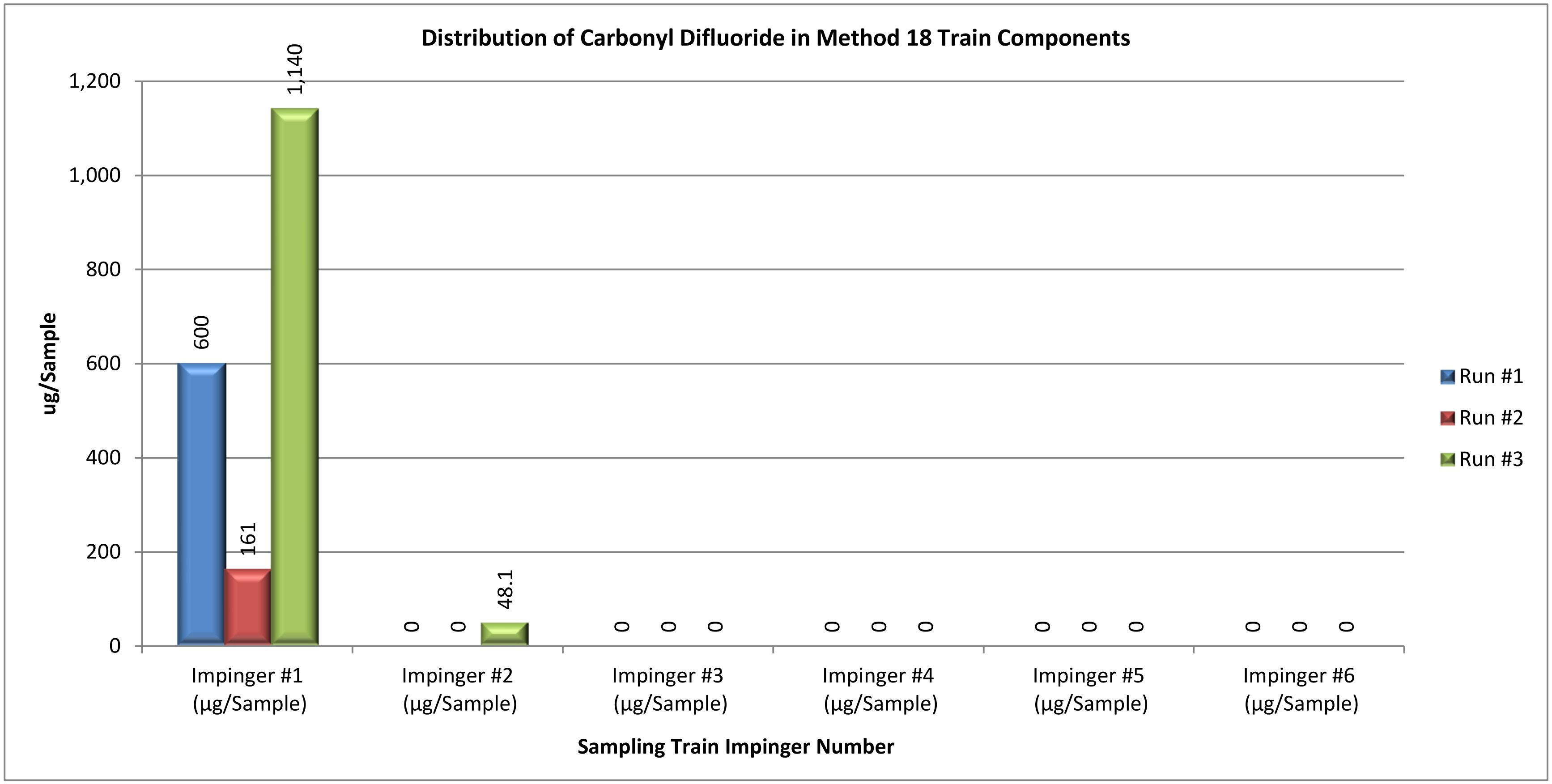


Figure 5-5. Polymer Waste Gas (Line #2) Modified Method 18 COF_2 Capture

Run No.	Impinger #1 (µg/Sample)	Percent (%) Impinger #1	Impinger #2 (µg/Sample)	Percent (%) Impinger #2	Impinger #3 (µg/Sample)	Percent (%) Impinger #3	Impinger #4 (µg/Sample)	Percent (%) Impinger #4	Impinger #5 (µg/Sample)	Percent (%) Impinger #5	Impinger #6 (µg/Sample)	Percent (%) Impinger #6	Train Total (µg)
1	468	0%	40.8	0%	5.56	0%	0	0%	0	0%	0	0%	514
2	499	0%	38.8	0%	0	0%	0	0%	0	0%	0	0%	538
3	1,350	0%	127	0%	23.0	0%	0	0%	0	0%	0	0%	1,500

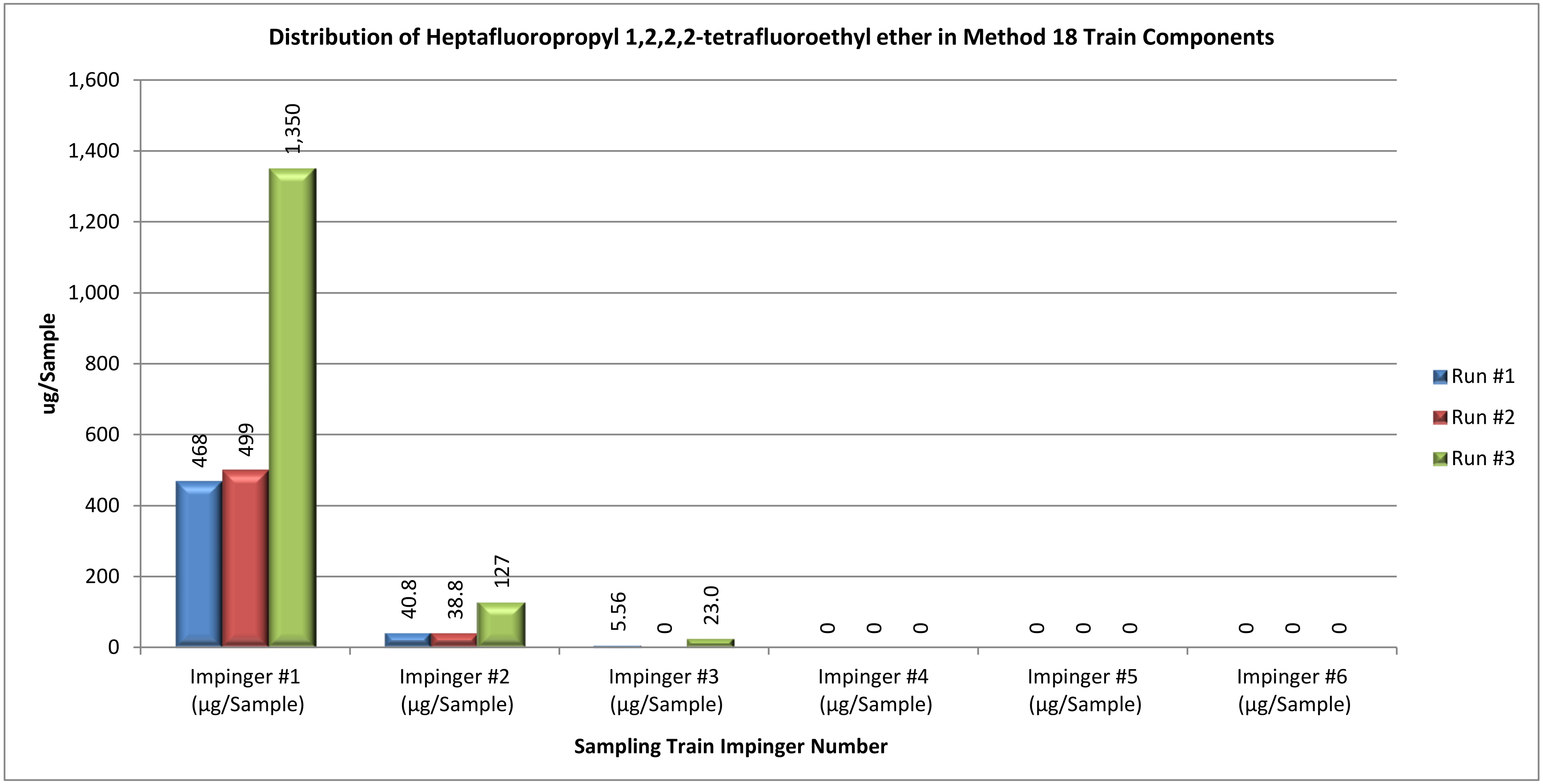


Figure 5-6. Polymer Waste Gas (Line #2) Modified Method 18 Fluoroether E-1 Capture

Run No.	Impinger #1 (µg/Sample)	Percent (%) Impinger #1	Impinger #2 (µg/Sample)	Percent (%) Impinger #2	Impinger #3 (µg/Sample)	Percent (%) Impinger #3	Impinger #4 (µg/Sample)	Percent (%) Impinger #4	Impinger #5 (µg/Sample)	Percent (%) Impinger #5	Impinger #6 (µg/Sample)	Percent (%) Impinger #6	Train Total (µg)
1	50,200	62.3%	15,300	19.0%	10,600	13.2%	3,480	4.32%	827	1.03%	154	0.191%	80,561
2	76,900	67.4%	32,900	28.8%	3,940	3.45%	273	0.239%	50.3	0.0441%	0	0%	114,063
3	109,000	53.7%	57,900	28.6%	25,600	12.6%	8,540	4.21%	1560	0.769%	202	0.100%	202,802

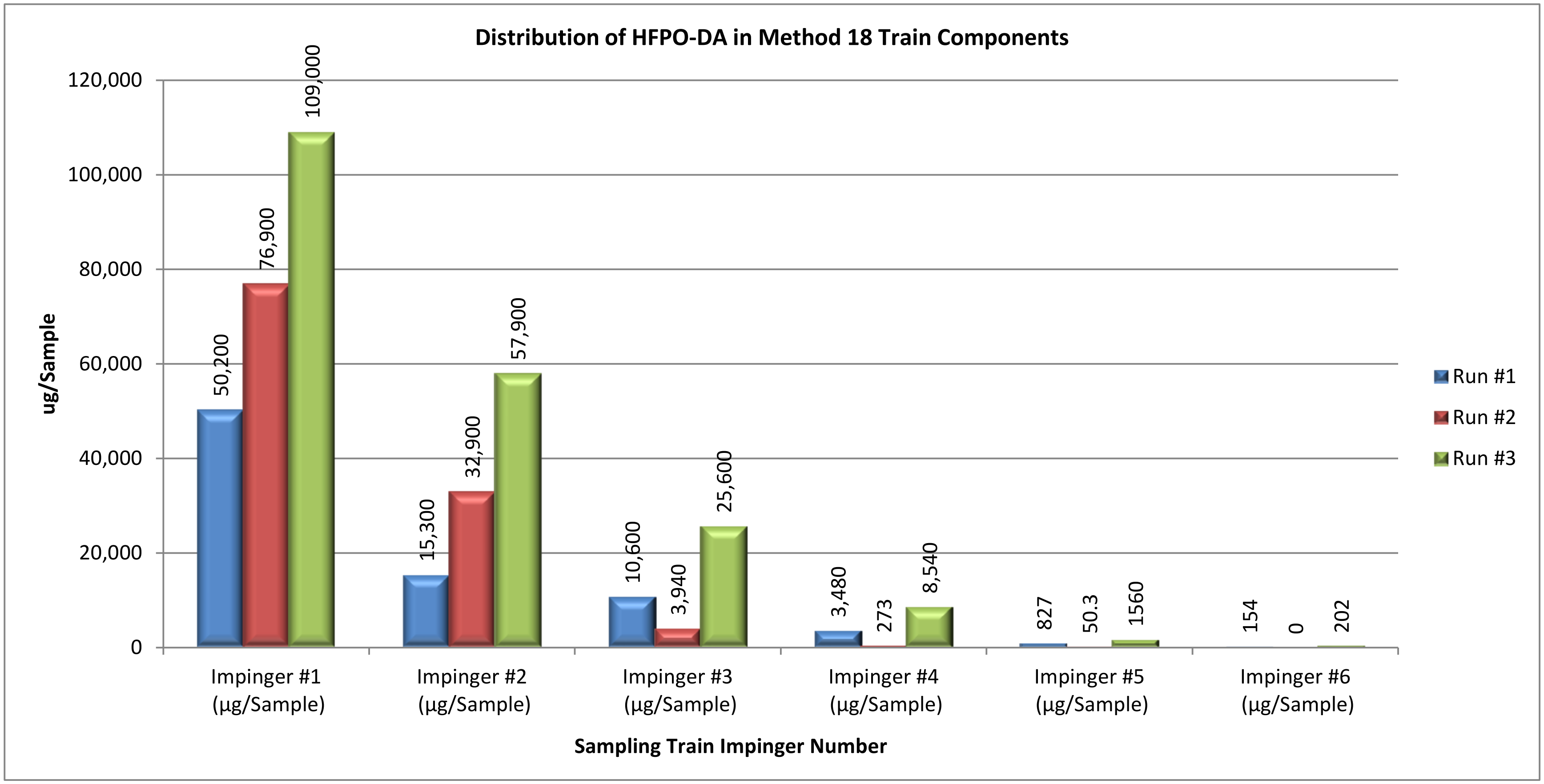


Figure 5-7. Polymer Waste Gas (Line #2) Modified Method 18 HFPO-DA Capture

6.0 CONCLUSION

The Chemours thermal oxidizer is controlling PFAS emissions at an average efficiency exceeding 99.99951%, demonstrating compliance with the consent order requirement to control all PFAS at an efficiency of 99.99%.