ESTCP

FINAL REPORT

ARFF Apparatus Disassembly and Characterization

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The Department of Defense (DoD) has many fire suppression systems impacted by residual per-and polyfluoroalkyl substances (PFAS), as a result of the use of Class B foams such as aqueous film-forming foam. This Final Report describes the activities to disassemble and analyze PFAS content on the on-board foam system components on an aircraft rescue and firefighting apparatus. This report provides an overview of the demonstration, summarizes the associated performance objectives, provides a brief DoD site description, details both the laboratory work and field deployment, and provides a summary level description of indicative costs, schedule, and project team organization. The objective of this project was to develop an understanding of the PFAS distribution within the individual components of an ARFF apparatus on-board foam system, costs for replacement of the on-board foam system, out-of-service time required for cleaning, and the extent of replacement required to successfully achieve PFAS removal from an on-board foam system.

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ACRONYMS AND ABBREVIATIONS

%	percent
ARFF	aviation rescue and firefighting
AFFF	aqueous film forming foam
COCs	chains of custody
CIC	combustion ion chromatography
DoD	United States Department of Defense
DP	Demonstration Plan
EPA	United States Environmental Protection Agency
FR	Final Report
GNG	Go/No-Go
HDPE	high density polyethylene
IDW	investigation derived waste
IPRs	In-Progress Reviews
LOQ	limit of quantification
MFP	Monthly Financial Report
QPR	Quarterly Progress Report
PFASs	per- and polyfluoroalkyl substances
PFOS	perfluorooctanesulfonic acid
PFOA	perfluorooctanoic acid
PI	Principal Investigator
RRAD	Red River Army Depot
SSM	Site Selection Memo
TT	Technology Transfer
TOF	total organic fluorine
TOP	total oxidizable precursor
U.S.	United States

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- Red River Army Depot: Brandon Dove, Kristal Jewell

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ABSTRACT

INTRODUCTION AND OBJECTIVES

The United States (U.S.) Department of Defense (DoD) has many fire suppression systems impacted by residual per-and polyfluoroalkyl substances (PFAS), as a result of the use of Class B foams such as aqueous film forming foam. This Final Report for ARFF Apparatus Disassembly and Characterization (Environmental Security Technology Certification Program Project ER21-7229) describes the activities to disassemble and analyze PFAS content on the on-board foam system components on an aircraft rescue and firefighting apparatus. The work was completed in accordance with Contract W912HQ21C0055. This report provides an overview of the demonstration, summarizes the associated performance objectives, provides a brief US DoD site description, details both the laboratory work and field deployment, and provides a summary level description of indicative costs, schedule, and project team organization. The objective of ER21-7229 was to develop an understanding of the PFAS distribution within the individual components of an ARFF apparatus on-board foam system, costs for replacement of the on-board foam system, out-of-service time required for cleaning, and the extent of replacement required to successfully achieve PFAS removal from an on-board foam system.

TECHNOLOGY DESCRIPTION

This project systematically evaluated the PFAS impacts and cost replacement options for components of an on-board foam system on an Oshkosh T-1500 (ARFF apparatus). Prior to removal of the components for assessment, a series of three baseline water flushes were conducted on the ARFF apparatus on-board foam system in place, with PFAS rinsate concentrations measured after each flushing event. Following water flushing, the on-board foam system was disassembled and removed components were sent to the Arcadis Treatability Laboratory for testing to determine the residual PFAS concentrations on the individual components. Following full replacement of the on-board foam system components, another series of three water flushes were conducted, and the PFAS concentrations in the rinsate were measured. Project data was analyzed and used to support the assessment of the cost-benefit relationship between cleaning versus replacement and to develop guidance for foam replacement.

PERFORMANCE AND COST ASSESSMENT

Results from the characterization of an on-board foam system demonstrated that greater than 99% of total post-total oxidizable precursor (TOP) assay PFAS were removed during baseline flushing, and 120 mg of post-TOP assay PFAS remaining on the components after the baseline flush. The costs of labor and materials for a total ARFF system replacement would exceed $350,000, but the results from the current study suggest that may not be necessary and that a subset of critical PFAS-containing components could be strategically replaced to significantly reduce costs while still maintaining performance.

IMPLEMENTATION ISSUES

There were significant delays in analytical laboratory turnaround times (TAT), particularly for Method 1633, with average TATs at 4 months and in some cases as high as 10 months. Despite previous success of wipe sampling, analytical issues were encountered with extraction recoveries and PFAS concentrations were considerable underestimated. The ARFF apparatus that was used for this study was removed from service before complete system reconstruction and rebound testing could be performed.

PUBLICATIONS

Anderson, J; Parker, B.; Guillette, T.C.; Liles, D; Wisner, B; Koropeckyj-Cox, L; Lang, J. Characterization of Residual PFAS Content in the Firefighting Foam Delivery System of an ARFF Vehicle. Submitted to Chemosphere 2024.

EXECUTIVE SUMMARY

INTRODUCTION

Aqueous film forming foam (AFFF) is known to contain per- and polyfluoroalkyl substances (PFAS), which are used in these products for their foaming, film forming, and heat-resistant properties. AFFF was first developed in the 1960s and was rapidly adopted as a superior alternative to previous protein based foams (Darwin 2004). In the United States (US), certified airports are required to maintain a minimum number of aircraft rescue and firefighting (ARFF) vehicles carrying AFFF and a foam discharge capacity based on their 'Airport Index' (FAA 2013). Many fire suppression systems, including ARFF vehicles, are impacted by residual entrained PFAS resulting from exposure to AFFF, which has been known to contain >10 g/L of total PFAS (Houtz, Higgins et al. 2013).

Companies manufacture alternative PFAS-free firefighting formulations (Bioex 2024, Foam 2024, PerimeterSolutions 2024), and the US Department of Defense (DoD) has published the Military Performance Specification (Mil-Spec) for PFAS-free firefighting formulation use on land with fresh water (USDoD 2023). There are an increasing number of states and countries promulgating regulations around the manufacture, sale, release and/or use of PFAS containing AFFF (Washington 2018, Colorado 2019, Allan 2020, Colorado 2020, Congress 2021, Resources 2022, Alaska 2023).

PFAS residuals on wetted fire suppression system surfaces have complicated the foam transition process. These residuals have been shown to be present on materials that have been in contact with highly concentrated PFAS-containing materials like AFFF (Lang, McDonough et al. 2022, Dahlbom, Bjarnemark et al. 2024). PFAS are known to self-assemble and coat surfaces at liquid/solid interfaces to form water resistant coatings and can therefore be difficult to fully remove from surfaces. If ARFF foam systems are not properly cleaned prior to replacement PFAS-free firefighting formulation being added, PFAS can dissolve from the surfaces of the system and release into the new PFAS-free firefighting formulation (Ross and Storch 2020). Lang et al. (2022) previously demonstrated that stainless steel AFFF concentrate pipe can amass approximately 10 $\mu g/cm^2$ of measurable surface-associated PFAS (post-TOP assay). Dahlbom et al. (2024) demonstrated almost 100 $\mu g/cm^2$ of measured PFAS surface residuals on galvanized steel AFFF piping, 0.01 to 0.1 $\mu g/cm^2$ on an AFFF concentrate tank, almost 1 $\mu g/cm^2$ on a handheld fire extinguisher, and almost 10 $\mu g/cm^2$ on a fire hose (post-TOP assay) (Dahlbom, Bjarnemark et al. 2024).

The overall objective of this work was to characterize PFAS residual mass on the wetted surfaces of ARFF vehicle on-board fire suppression system components from the water, mixed foam, and foam concentrate systems with various geometries, materials of construction, and locations within the fire suppression system. ARFF vehicles typically have both a tank containing water and a tank containing AFFF concentrate. When foam is needed, the water and foam are piped to a proportioner where they are mixed at the appropriate ratios (e.g. 3% or 6%). Mixed foam is then piped to a variety of turrets or outlets for handlines. A more complete understanding of the extent of PFAS impacts in an on-board fire suppression system will provide information to determine the best course of action to achieve a substantially PFAS-free system and prevent future release to the environment.

OBJECTIVES

The objective of this project was to understand the PFAS composition within an ARFF apparatus on-board foam system and by:

- Characterizing PFAS distribution within individual components of an ARFF on-board foam system, including both system location (e.g., water, foam, mixed), part material (e.g., brass, stainless steel, etc.), and part shape (e.g., straight, bent).
- Determining the total costs for labor and materials associated with the complete replacement on the on-board foam system inclusive of the out-of-service time required for cleaning.
- Evaluating the extent of replacement needed to achieve successful PFAS removal from an on-board foam system.

TECHNOLOGY DESCRIPTION

This technology comprises a combination of established rinsing and extraction techniques to determine PFAS impacts in the components of an ARFF vehicle foam system. This project ultimately calculated PFAS residuals on the interior surfaces of individual ARFF vehicle foam system components. Data on PFAS residuals on specific components of the ARFF vehicle foam system will assist the DoD with determining whether cleaning or replacement of individual components will be more cost effective.

Methanol has been demonstrated to effectively remove PFAS from surfaces in laboratory soil extraction experiments (Washington, Henderson, Ellington, Jenkins, & Evans, 2008). The Arcadis Treatability Laboratory (ATL), located in Durham, North Carolina, systematically exposed the wetted components to methanol to extract PFAS. Analysis of the PFAS content in samples were sent to SGS AXYS and measured via EPA Method 1633 with and without undergoing a total oxidizable precursor (TOP) assay. A subset of components were submitted to subcontracted laboratories for combustion ion chromatography (CIC) analysis to quantify total organic fluorine (TOF), particle-induced gamma emission spectroscopy (PIGE) to quantify fluorine content remaining on part, and x-ray photoelectron spectroscopy (XPS) to measure surface elemental composition, including percent fluorine.

The specific on-board foam system evaluated in this study was on an Oshkosh T-1500 (ARFF apparatus) with a 210-gallon plastic foam tank and 1,500-gallon polypropylene water tank located at Red River Army Depot (RRAD) in Texarkana, Texas. The fire suppression system on the ARFF vehicle contains three distinct zones: water supply “water”, foam concentrate only “foam”, and mixed fire water “mixed.” For the current system evaluated, forty percent of components were constructed of stainless steel, but there were also several composed of plastic and brass. There were a variety of geometries including the foam and water tanks, hoses, straight pipes, valves, and elbows. Additionally, components were distributed among the foam, mixed, and water systems. Although the exact same components may not translate to all ARFF on-board foam systems, trends within the part types and locations may be more broadly applied.

The ATL received 82 unique catalogued components from the ARFF's on-board firefighting formulation delivery system as well as the foam and water tanks, which were split up into multiple baffles. A major advantage of characterizing PFAS composition for individual components is that rather than having to completely replace all 82 components within the foam system, components can be prioritized based on PFAS mass loading. For the current system evaluated, replacing just three specific elements (two hoses and one valve) would result in a 50% decrease in PFAS mass. Expanding this approach to include other critical components including the water tanks and components within the foam system would result in greater than 90% of the total PFAS mass reduction. This tactic not only offers a cost-effective alternative to comprehensive system replacement, but also allows for the optimization of PFAS contamination efforts for foam transitions and enhances operational sustainability.

PERFORMANCE ASSESSMENT

In characterizing PFAS impacts within the ARFF vehicle foam system, the performance objectives centered on the determination of PFAS residuals on individual components and the distribution among component types and location within the system. Most of the results and data from the system flushing and component PFAS characterization will be published in Anderson et al. (submitted 2024; Appendix B).

The initial ARFF vehicle rinsing procedures demonstrated a moderate effectiveness at the removal of PFAS from system components (**Table ES-1**). The baseline rinsing event showed significant removal of PFAS in the foam-only portion of the system, indicating successful flushing of PFAS. The presence of PFAS in the rinse of the water-only system, albeit at much lower levels, suggests the potential for cross-contamination between the water, mixed and foam systems. This raises concern about unintended dispersion of PFAS into areas where they were not intentionally, possibly exacerbating contamination levels. While the rinsing procedures demonstrated promise in reducing PFAS mass on system components, residual PFAS remaining after rinsing highlights the need for comprehensive cleaning protocols or replacement of components altogether.

Table ES-1. ARFF Vehicle Results of Total PFAS Measured in Water and Foams Systems During the Baseline and Final Rinsing Events.

			Total Measured Mass Removed (mg)*			
			Rinse 1	**Rinse 2**	**Rinse 3**	**Total**
Baseline Event	**Water System**	**Pre-TOP**	0.67	0.57	0.44	1.7
		Post-TOP	2.4	13	7.8	23
	Foam System	**Pre-TOP**	930	78	8.8	1020
		Post-TOP	19000	510	55	19600
Final Event	**Water System**	**Pre-TOP**	0.020**	0.021	0.024	0.065
		Post-TOP	0.029	0.032	0.047	0.108
	Foam System	**Pre-TOP**	0.035	0.033	0.045	0.113
		Post-TOP	0.089	0.092	0.072	0.253

* Total measured mass removed calculated as the sum of the PFAS concentrations in the bulk rinsing water times the volume of rinsing water

Prioritizing critical components for replacement based on PFAS mass loading offers a strategic approach to achieving substantial reductions in over PFAS contamination levels. The results from this project successfully demonstrated significant differences in PFAS mass loadings among both system locations and component materials. Components from the foam and mixed systems had greater PFAS levels than components in the water only system. In all systems, the individual PFAS in greatest abundance were PFOS and 6:2 FtS, although there were differences in the relative amounts of these two compounds among system types. Components made of rubber and brass generally had greater PFAS concentrations than stainless steel and plastic components, indicating that there is a variation of PFAS loading based on material composition.

Some components with significantly larger surface areas, like the foam and water tanks, contained higher overall PFAS residuals despite their lower PFAS concentration, highlighting the importance of considering surface area when addressing PFAS contamination in system components.

Table ES-2. Total Mass of PFAS Residual Measured on Components Removed from Each Section of the ARFF Fire Suppression System.

System	Pre-TOP Total Mass (mg)	Post-TOP Total Mass (mg)
Water	1.5	2.6
Mixed	25.0	62.0
Foam	18.0	51.0
Total	**44.0**	**120**

Surface total fluorine composition may also play a role in assessing PFAS contamination levels and distribution within an ARFF system. While it was limited as a direct proxy for PFAS concentration due to variations among component materials, XPS analysis of total fluorine offered valuable insights with evaluating components of the same material type. The significantly higher percentage of fluorine on components from the foam system compared to the mixed or water systems indicates potential differences in PFAS contamination across system components, as confirmed by Method 1633 analysis. Monitoring surface fluorine reductions after extraction with XPS provides a practical method for evaluating PFAS extraction efficiency. By tracking changes in surface fluorine content before and after extraction procedures, practitioners can gauge the effectiveness of cleaning protocols in removing PFAS contaminants. In general, XPS detection limits can range from 0.1-1 atomic percent. Understanding surface fluorine composition through XPS analysis enables the development of targeted cleaning strategies to enhance mitigation efforts in ARFF operations, particularly during foam transitions. By leveraging XPS insights, operators can optimize cleaning procedures, assess contamination levels accurately, and implement tailored approaches to manage PFAS risks effectively in ARFF systems.

The final rinsing event conducted after the new components were installed were significantly reduced (>99%) compared to the baseline rinsing event (**Table ES-1**). However, there were still low level PFAS concentrations in samples from both the foam only and water only portions of the ARFF vehicle. The total PFAS concentrations in the rinsates for the water and foam systems both exceeded 70 ng/L (Pre-TOP: 87.7-141 ng/L; Post-TOP: 147-318 ng/L). Some of that PFAS is likely a result of the water provided for the rinsing, although even taking that into account the total PFAS concentrations are still around or above 70 ng/L.

Assuming the system was at one time completely full, if all the residual PFAS mass from the water and foam systems post-baseline flushing had been successfully flushed in a follow-up event, the total PFAS concentration for the water and foam systems would have been 3,500 ng/L and 640,000 ng/L, respectively. These results indicate that achieving less than 70 ng/L may be hard to achieve even using brand new components.

COST ASSESSMENT

The operational costs associated with an ARFF apparatus on-board foam system complete replacement involves the transportation of the truck, the labor and expertise required for the disassembly and inventory management of individual components and acquisition of new components, particularly for custom or retroactively fitted components, the material cost for the replacement components, the labor and expertise required for the reassembly of the system, time cost for the truck being out of operation during replacement, and disposal costs for original components and potentially hazardous materials.

An itemized cost breakdown of labor and individual components was not provided by the DoD, but the total costs associated with labor were $110,502.58 and material costs were $263,626.84, for a total cost of approximately $363,000. Given the results from this study, a significant reduction in total costs could be achieved by targeting critical components within the system for replacement. For the current system, just five components (two hoses from the mixed system, one brass valve from the foam system, the water tank, and one stainless-steel part from the foam system) could be replaced rather than all 82 components, and it would still result in the removal of 90% of the total residual PFAS.

IMPLEMENTATION ISSUES

Analytical issues encountered during the ARFF baseline rinse analysis and component characterization include high detection limits, poor oxidation of some TOP assay samples, and extended turnaround times. The high detection limits were a result of dilution factors needed to accommodate high concentrations of PFOS and 6:2 FtS. In the most extreme case, concentrations in the mg/L range were reported as estimated data because of the high dilution factors. The lab turnaround times for Method 1633 were on average 4 months, and in some cases, as high as 10 months.

Some components were too large to extract as a whole part, and were not able to be cut down, so they required alternative extraction methods. Methanol wipe extractions previously demonstrated good performance and agreement with typical methanol extractions. However, in the current project there were significant issues with wipe extraction efficiencies resulting in an underestimation of PFAS and decreased statistical power due to wipe sample exclusions. Although previous work had demonstrated good agreement between wipe extractions and MeOH extractions, the poor recoveries here indicate that wipe extractions are not always suitable and may be dependent on material type.

This project also ran into several logistical issues involved in the procurement and installation of new components. These issues are identified below:

1. There were many components that were out of stock and required fabrication,

2. Some components that were custom manufactured for the truck and were no longer available.
3. Some components were provided by the manufacturer, but despite having the correct part number were manufactured to revised specifications that were not compatible with the T-1500 disassembled.
4. Some components in the system that weren't initially identified by the manufacturer for replacement. These were retrofitted components that were not provided by the original equipment manufacturer, and thus weren't included on any schematics/part lists.

The challenges associated with acquiring new components resulted in the truck sitting out of service for 15 months before being decommissioned, making a rebound test impossible.

RECOMMENDATIONS

The execution of this project has provided a unique opportunity to view the complexities of managing a foam transition process. Specific to this project is the goal to completely replace the wetted system inside a vehicle to remove PFAS and prepare the vehicle to operate without PFAS contamination derived from AFFF. As was observed from characterization of parts removed from the ARFF apparatus, a three times water rinse is not sufficient to remove PFAS from the wetted surfaces of an apparatus in the water or foam systems. Further, with PFAS observed in the post-reassembly rinse process, full replacement of a wetted system may not serve to rid the vehicle of all PFAS since use of PFAS in the manufacturing process or as a manufacturing aid could impart PFAS onto the newly manufactured surfaces of a vehicle.

Because of the complexity of a program replacing a full system worth of components, an abbreviated program consisting of replacing a small subset of components that represent approximately 90% of PFAS present in the system would serve to reduce the overall cost and downtime related to transition by focusing the supply chain on a smaller number of parts that could be acquired more quickly. This small list of parts identified in the report are: a pilot valve sensing hose, a hose in the brass manifold box, brass valve downstream of the foam fill riser, a stainless steel part upstream of the discharge and foam metering manifold, and the water tank.

The data generated in this study does provide information that a partial system replacement coupled with a single water rinse may provide an acceptable alternative to full system replacement for DoD equipment foam transition. With a combined strategy may come additional project challenges that would threaten its viability, including, but not limited to: availability of replacement parts, protracted lead time for identified and unavailable parts, extent of disassembly required to access, remove, and replace identified parts, and the cost of replacement of parts identified. The extent of the effectiveness of a partial system replacement and single water rinse strategy would require additional work be completed to characterize a system subjected to this treatment process.

1.0 INTRODUCTION

This Final Report for ARFF Apparatus Disassembly and Characterization (Environmental Security Technology Certification Program Project ER21-7229) describes the activities to disassemble and analyze per- and polyfluoroalkyl substances (PFAS) content on the on-board foam system components on an aircraft rescue and firefighting (ARFF) apparatus. The work was completed in accordance with Contract W912HQ21C0055. This report provides an overview of the demonstration, summarizes the associated performance objectives, provides a brief United States (U.S.) Department of Defense (DoD) site description, details both the laboratory work and field deployment, and provides a summary level description of indicative costs, schedule, and project team organization. The points of contact for the project are provided in **Appendix A**.

1.1 BACKGROUND

The U.S. DoD has many fire suppression systems, including ARFF apparatuses, impacted by residual entrained PFAS resulting from the use of AFFF. PFAS are known to self-assemble and coat surfaces at liquid/solid interfaces to form waterproof coatings and can therefore be difficult to fully remove from surfaces. If integrated ARFF foam systems are not properly cleaned and replacement PFAS-free firefighting formulation is added, PFAS can dissolve from the surfaces of the system and release into the new firefighting formulations (Horst, Quinnan et al. 2021).

Amphiphilic PFAS in Class B foams marketed as aqueous film-forming foams (AFFF) are well known to self-assemble into multiple bilayers on solid surfaces at reasonably low (e.g., milligram per liter [mg/L]) concentrations in water, forming multilayered vesicles and lamella sheets which comprise supramolecular assemblies (Krafft, Guilieri and Riess 1993, Barenholz 1996, Banks 2000, Kissa 2001, Gladysz 2004). The formation of self-assembled surface-bound structures are similar to the properties of waterproof surface coating, which can form a reservoir of potentially millions of PFAS layers that are slowly released back into water. The presence of a combination of supramolecular assemblies has been previously reported and visualized using scanning electron microscopy (SEM) or transmission electron microscopy (Shen, Ou-Yang et al. 2014, Shen, Ou-Yang et al. 2016).

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective of ER21-7229 was to use a DoD-provided ARFF apparatus to develop an understanding of the PFAS distribution within the individual components of an on-board foam system, evaluate the costs for replacement of the on-board foam system, the out-of-service time required for system replacement, and the extent of replacement required to achieve PFAS removal from an on-board foam system. This project includes laboratory-scale extraction of individual components of the ARFF apparatus on-board systems to define relative PFAS loading throughout the ARFF apparatus. This project did not aim to design specific procedures for complete or optimal extraction of PFAS from component surfaces in field cleaning activities. The information collected was used to inform a cost-benefit analysis of cleaning similar ARFF apparatuses or either the partial or full replacement of on-board foam system components to achieve a substantially PFAS-free foam system.

1.3 REGULATORY DRIVERS

Regulations restricting the use and release of AFFF containing PFAS are being proposed and promulgated throughout the world, with several enacted regulations addressing the use of PFAS-containing firefighting foam (Queensland 2016, Congress 2019, Legislature 2019, Allan 2020, Assembly 2021, Congress 2021, Congress 2021, Espinosa, Summers et al. 2021, Legislature 2021, Legislature 2021, Assembly 2022, Representatives 2022, Resources 2022, Alaska 2023). In 2016, Queensland, Australia was one of the first governments to ban PFAS use in firefighting foam (Queensland, 2016). The US 2020 National Defense Authorization Act (2020 NDAA) specified immediate prohibition of controlled release of PFAS-containing AFFF and contained a requirement for the Secretary of the Navy to publish a specification for PFAS-free firefighting formulation use and ensure it is available for use by DoD on October 1, 2023 (Congress 2019). Additionally, the 2020 NDAA includes a requirement that all DoD assets be transition from AFFF by October 2024, a date which may be subject to a one-year extension provided that necessary requirements are met. In addition to regulated usage, firefighting foam users are transitioning to PFAS-free firefighting formulations to reduce environmental liability in the event of a release, to reduce the cost of expensive containment systems and management of generated waste streams, and to avoid reputational damage.

2.0 TECHNOLOGY

2.1 TECHNOLOGY DESCRIPTION

This project systematically evaluated the PFAS impacts and cost replacement options for an on-board foam system on an Oshkosh T-1500 (ARFF apparatus) with a 210-gallon on-board foam tank and 1,500-gallon on-board water tank (**Figure 1**) provided by the U.S. DoD at Red River Army Depot (RRAD) in Texarkana, Texas.

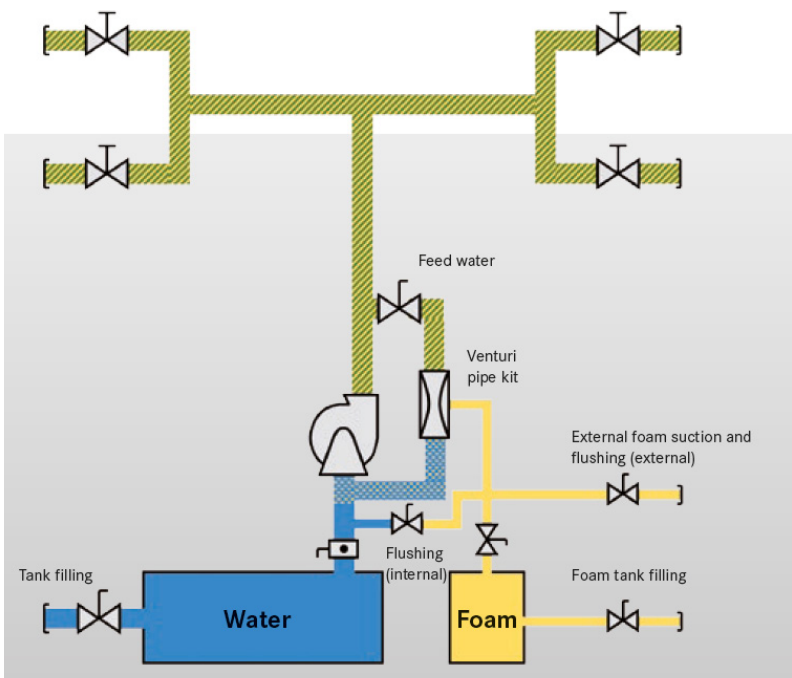

Figure 1. Example of a Venturi Proportioning System Typical of Many On-board Foam Systems in ARFF Apparatuses.

The figure shows the three distinct systems: water supply, concentrate supply, and foam delivery.

Prior to removal of the components, a series of three water flushes, consisting of 200 gallons of water per flush, were conducted on the ARFF apparatus at RRAD in April 2022 (**Figure 2**). The ARFF apparatus on-board foam system and water system were flushed with a series of three water rinses and PFAS rinsate concentrations were measured after each flushing event to provide information on water rinse effectiveness and efficiency. Water flushing consisted of filling the associated tanks with water passed through existing on-board piping followed by two hours of recirculation of the tank and associated piping using an off-board pump. Following water flushing, the on-board foam system was disassembled and removed components were sent to the Arcadis Treatability Laboratory (ATL) for testing to determine the residual PFAS concentrations on the individual components. Following full replacement of the on-board foam system components, another series of three water flushes were conducted, and the PFAS concentrations in the rinsate were measured. Project data was analyzed and used to support the assessment of the cost-benefit relationship between cleaning versus replacement and to develop guidance for foam replacement.

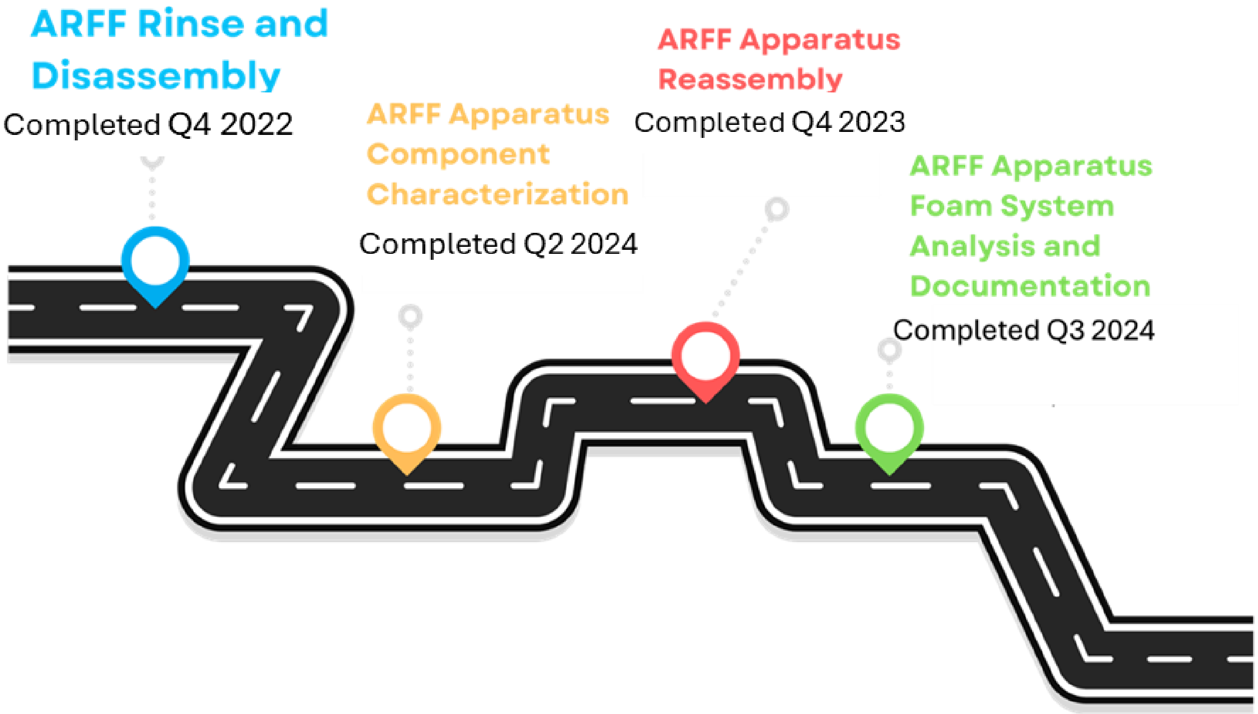

Figure 2. Chronological Summary of Major Project Events.

3.0 PERFORMANCE OBJECTIVES

Table 1. Quantitative Performance Objectives

Technical Objective	Data Requirement	Success Criteria	Results
Part-by-part total replacement costs of wetted components of on-board foam system	Operational data from ARFF apparatus component replacement consisting of: • Labor hours required for component removal and replacement • Per part cost for replacement of wetted components • Cost to transport ARFF for component replacement • Cost of procurement of components including tracking long-lead-time components	Quantifiable total costs can be developed for replacing each part or segment of components in ARFF apparatus for foam transition strategy development	The total costs associated with full foam system replacement are $110,502.58 (Labor) and $263,626.84 (Materials)
Characterization of the total mass of PFAS and fluorine on a wetted surface area basis contained on each on-board foam system component after 3X water rinse in the field	• Wetted surface area of each on-board foam system component • Speciated PFAS concentrations in the extraction media used for each component determined by EPA Method 1633, or equivalent • TOF concentrations in the extraction media used for each component determined by combustion ion chromatography (CIC) • Total fluorine (TF) concentration by particle induced gamma emission spectroscopy (PIGE) • Images of the wetted surface of components using SEM and x-ray photoelectron spectroscopy (XPS)	Data can be used to calculate the mass of PFAS and fluorine per wetted surface area on each system component and is sufficient to delineate the components or segments (group of components) with highest residual AFFF impacts	• Total mass of PFAS per surface area (TOP assay) on each system component • TOF per surface area on a subset of system components • Fluorine (%) on a subset of system components • PIGE on a subset of system components
Quantification of the impact of total system replacement on PFAS content in foam system	Analytical data and images using the following methods: • Speciated PFAS concentrations by EPA Method 1633 (pre-TOP assay), • TOF concentration by CIC	Total PFAS concentrations in rinse water are below 70 ppt 1 ppb TOF	Second mobilization third flush was not successful at achieving total PFAS of less than 70 ppt (Pre-TOP: 87.7-141 ng/L; Post-TOP: 147-318 ng/L) TOF concentrations were approximately 10 ppb.
	Speciated PFAS data by EPA Method 537M, or equivalent	Total PFAS concentrations in replacement foam remain below 1.0 micrograms per liter, or reporting limit for analysis of F3 foam concentrate, for all collected foam rebound samples.	No rebound due to decommissioned truck

4.0 SITE DESCRIPTION

ARFF rinsing and part disassembly were conducted at Red River Army Depot (RRAD) in Texarkana, Texas. The mission of RRAD is to provide ground combat and tactical systems sustainment maintenance operations. RRAD has a large amount of floor space dedicated to maintenance of a large variety of apparatus systems used by the Army, including ARFF apparatus.

Figure 3. ARFF Apparatus

5.0 TEST DESIGN

The methods of this project are demonstrated in Anderson et al. (2024). In brief, the test design included a preliminary water flush baseline characterization of the ARFF apparatus, complete disassembly of the on-board foam system, off-site components characterization, and ARFF apparatus reassembly with PFAS rebound characterization. An Oshkosh T-1500 with a 210-gallon foam tank and 1,500-gallon water tank located at Red River Army Depot in Texarkana, Texas was used for this study. Prior to removal of the on-board foam system components, a series of three baseline water flushes were conducted on the on-board foam system. Following the baseline water flushing, the on-board foam system was disassembled and individual components of the system were sent to the Arcadis Treatability Laboratory (ATL) in Durham, North Carolina. Several methods were developed to assess the PFAS residual concentrations on each component.

To assess the residual PFAS surface concentrations on each component, destructive sampling (e.g., cutting and solvent extraction) was used on applicable components including the tanks, hoses, and piping using methods from Lang et al. (2022). This destructive sampling method for PFAS surface content analysis was selected unless one of the following criteria was met: (a) the material was shown to be unstable when exposed to a methanol-based extraction solution (e.g., 95% methanol, 5% deionized water) over 24 hours in a compatibility pre-test performed on all non-metal materials tested; (b) the exterior of the component was painted or deemed dirty enough to potentially interfere with analytical instrumentation or potentially contaminated with PFAS; or (c) the component was deemed unable to be cut safely with the tools available (e.g., pumps, turrets, and some valves).

To assess the residual PFAS surface concentrations on the components deemed unsuitable for destructive sampling, cap and fill sampling or wipe sampling was performed. If a component had Victaulic ends on both sides but was unable to be destructively sampled, it was sampled using a cap-and-fill method. Otherwise, the component was extracted and analyzed via a wipe sampling method. All MeOH aliquots and wipe extracts were sent to SGS for PFAS analysis before and after TOP assay via Method 1633. In addition to PFAS analysis, a subset of MeOH extracts were went to PACE for TOF analysis.

To standardize measured PFAS and fluorine concentrations across methods and component types, all results were normalized to the component surface area measured by each individual method. Manual measurements of extracted component wetted surface areas were conducted with measurement tapes as well as electronic angle finders and electronic calipers. Three dimensional scans were conducted using the handheld EinScan HX scanner and processed by RZA Technologies. Some components were scanned both whole and disassembled or cut to facilitate accurate wetted surface area models. Hand measurements were used to provide quality assurance and control process for the scans. Hydraulic hoses were excluded from the scanning procedure.

RRAD personnel acquired and replaced wetted components for the fire suppression system in the ARFF vehicle with the objective of analyzing PFAS impacts on an entirely new system. Procurement of components took more than one year due to the age and complexity of the system and components that required custom fabrication for the ARFF apparatus. Following procurement of new replacement components for the fire suppression system on the apparatus, Arcadis re-mobilized to RRAD to perform a series of final water rinses on the water and foam portions of ARFF apparatus.

Due to the system configuration, final water rinsing could not be conducted on the mixed fire water portion of the ARFF vehicle.

Following full replacement of the on-board foam system components, another series of three water flushes were conducted, and the PFAS concentrations in the rinsate were measured. Project data was analyzed and used to support the assessment of the cost-benefit relationship between cleaning versus replacement and to develop guidance for foam replacement.

6.0 SAMPLING RESULTS

6.1 BASELINE CHARACTERIZATION

The results of the baseline characterization are demonstrated in Anderson et al. (2024). Baseline water flushes were intended to rinse out existing PFAS residue and characterize water soluble PFAS impacts within the ARFF vehicle on-board foam system. For the foam system rinse, the concentration of PFOS significantly decreased with each sequential rinse, with little differences in concentration between the pre- and post-TOP assay analysis (**Table 2**). For the water system rinse, greater PFOS was found in the second and third rinses than the initial, and there was much greater variation between the pre- and post-TOP assay analysis. Results from baseline rinsing demonstrated that significant amounts of PFAS were removed from the foam-only portion of the system, with a lesser amount found in the water system (**Table 3**). This presence of PFAS in the water system rinse was unexpected, likely a result of backflow from a faulty check valve allowing foam residues to enter the water tank. The PFAS profiles indicated different compositions between the foam and water systems, possibly due to historical usage of different types of AFFFs.

Table 2. Comparison of PFOS Concentration Pre- and Post-TOP Assay from the Baseline Rinse

Sample ID	Pre-TOP (ng/L)	Post-TOP (ng/L)	% Difference
Foam System Rinse 1	762,500	834,000	9%
Foam System Rinse 2	39,200	37,850	-3%
Foam System Rinse 3	3,510	4,745	35%
Water System Rinse 1	47.1	80.6	71%
Water System Rinse 2	236	429	82%
Water System Rinse 3	245	70.3	-71%

Table 3. ARFF Vehicle Rinsing Event Results.

Individual PFAS concentrations for each rinse in the baseline and final rinsing events are demonstrated in the Appendix C data tables.

<table>
<tr><th></th><th></th><th></th><th colspan="4">Total Measured Mass Removed (mg)*</th></tr>
<tr><th></th><th></th><th></th><th>Rinse 1</th><th>Rinse 2</th><th>Rinse 3</th><th>Total</th></tr>
<tr><td rowspan="4">Baseline Event</td><td rowspan="2">Water System</td><td>Pre-TOP</td><td>0.67</td><td>0.57</td><td>0.44</td><td>1.7</td></tr>
<tr><td>Post-TOP</td><td>2.4</td><td>13</td><td>7.8</td><td>23</td></tr>
<tr><td rowspan="2">Foam System</td><td>Pre-TOP</td><td>930</td><td>78</td><td>8.8</td><td>1020</td></tr>
<tr><td>Post-TOP</td><td>19000</td><td>510</td><td>55</td><td>19600</td></tr>
<tr><td rowspan="4">Final Event</td><td rowspan="2">Water System</td><td>Pre-TOP</td><td>0.020**</td><td>0.021</td><td>0.024</td><td>0.065</td></tr>
<tr><td>Post-TOP</td><td>0.029</td><td>0.032</td><td>0.047</td><td>0.108</td></tr>
<tr><td rowspan="2">Foam System</td><td>Pre-TOP</td><td>0.035</td><td>0.033</td><td>0.045</td><td>0.113</td></tr>
<tr><td>Post-TOP</td><td>0.089</td><td>0.092</td><td>0.072</td><td>0.253</td></tr>
</table>

* Total measured mass removed calculated as the sum of the PFAS concentrations in the bulk rinsing water times the volume of rinsing water

**Final event masses demonstrated as the sum of the average individual PFAS concentrations

A comparison of the speciation in PFAS data between the water and foam systems reveals PFOS and 6:2 FtS were the dominant PFAS present in both the water and foam systems, but that the water system had a much greater contribution of 6:2 FtS relative to PFOS than the foam system (**Figure 4**). The post-TOP assay results for both systems is primarily short chain PFCAs, with some lingering 6:2 FtS that remained unoxidized.

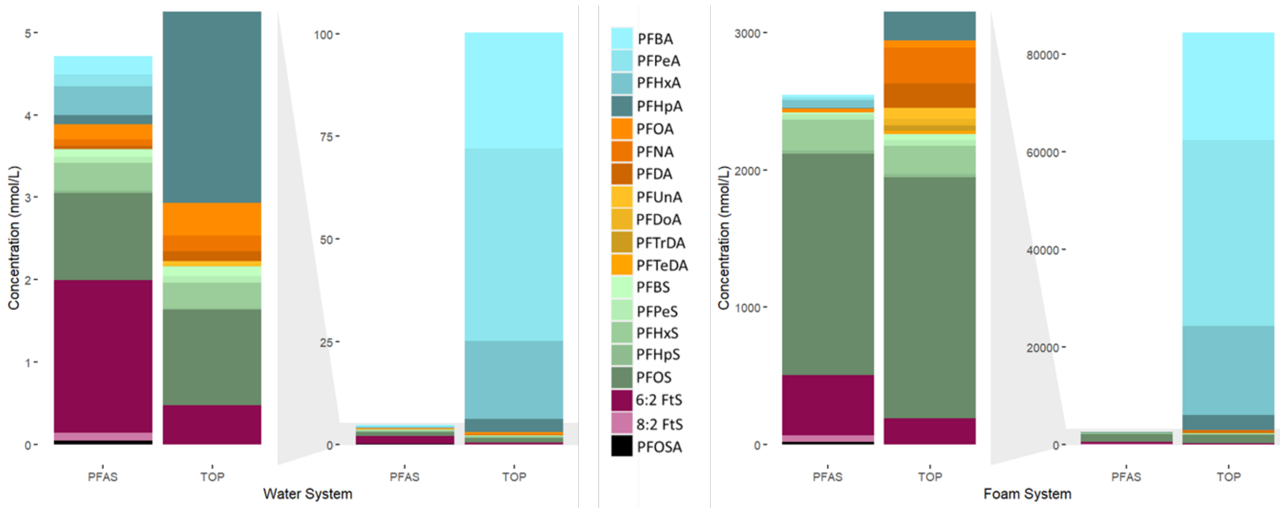

Figure 4. Baseline Rinse PFAS Composition Presented Molar Concentration Based on Sum of Individual PFAS of Three Rinses of Water System and Foam System.

Data is presented as PFAS (Method 1633) and TOP (Method 1633 after TOP assay).

6.2 OFF-SITE COMPONENTS CHARACTERIZATION

The results of the off-site component characterization are demonstrated in Anderson et al. (2024) and full data tables are in Appendix D. The total PFAS mass on each part was calculated based on the measured surface concentrations and the total surface area of the part. The total measured PFAS mass in each ARFF vehicle system was then calculated as the sum of the PFAS masses on each part in the system using both pre- and post-TOP assay data (**Table 4**). For all of the residual PFAS extraction measurements, the pre-TOP assay concentrations were lower than the post-TOP assay concentrations indicating the presence of unmeasured precursors. For the foam system, the total residual PFAS mass measured with pre- and post-TOP assay (18 mg and 51 mg, respectively - **Table 4**) was orders of magnitude lower than the mass removed with rinsing (1,020 mg and 19,600 mg, respectively - **Table 3**), indicating that the baseline rinse was able to flush out AFFF and some self-assembled PFAS.

Table 4. Total Mass of PFAS Residual Measured on Components Removed from Each Section of the ARFF Fire Suppression System.

System	Pre-TOP Total Mass (mg)	Post-TOP Total Mass (mg)
Water	1.5	2.6
Mixed	25.0	62.0
Foam	18.0	51.0
Total	**44.0**	**120**

The total measured residual PFAS mass on individual components of the water, foam, and mixed fire water system removed from an ARFF vehicle are shown in **Figure 5**. Results are presented as total measured mass of PFAS on each part (i.e. PFAS concentration * extraction volume). Most of the PFAS residuals were present on mixed and foam systems components (**Table 4**), with rubber and brass components having the greatest total measured PFAS mass. In general, surface area of components had minimal contributions to the total measured mass, indicating that the PFAS residual concentrations were more important to the total measured PFAS mass present on each part than the surface area. The notable exception to this conclusion were the foam and water tanks, which had total wetted surface areas that were orders of magnitude greater than the other components. For plastic components with large total wetted surface area (i.e. foam and water tanks), the overall mass on these components was larger than other components even though the corresponding measured PFAS residual extraction concentrations were lower compared to other material types.

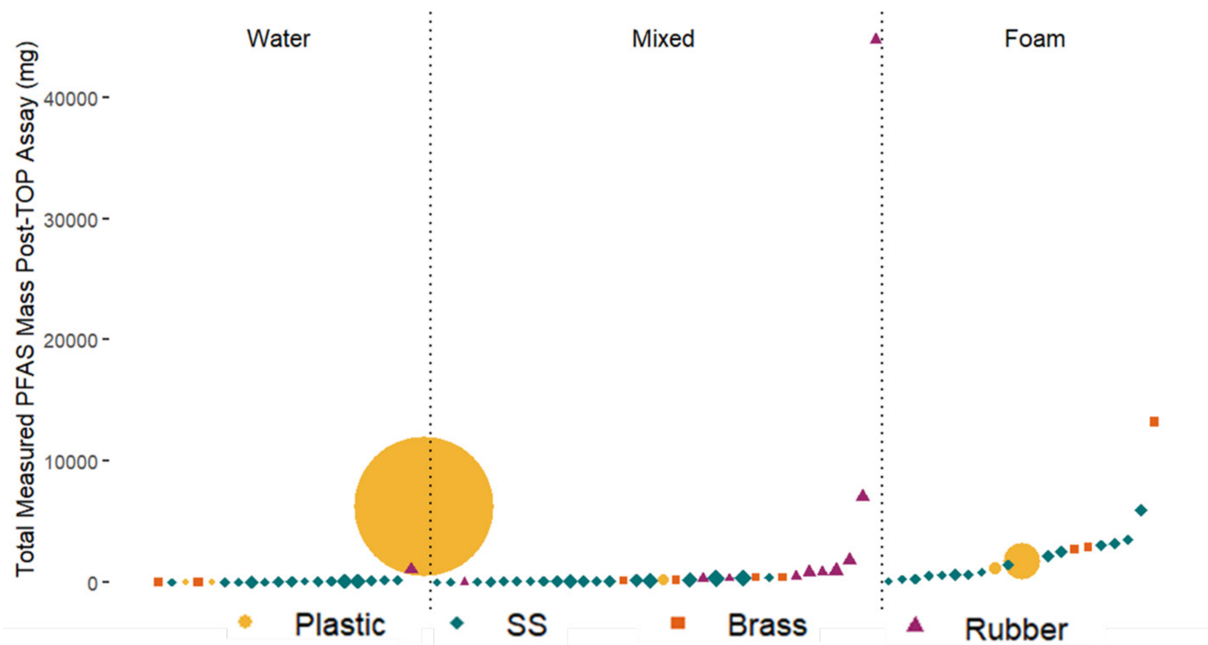

Figure 5. All Truck Components Listed in Ranked order from Lowest Total PFAS Mass to Greatest for Each System, with Marker Diameters Scaled to the Part Surface Area (Larger = Higher Surface Area).

6.3 ELEMENTAL SURFACE CONTENT – XPS

Surface fluorine composition ranged from 0-30% for individual components (**Figure 6**). There was poor correlation between fluorine composition and total PFAS mass pre- or post-TOP assay ($r^2 < 0.3$), so XPS is not considered a viable proxy for PFAS concentration, particularly when comparing different material types. While it's possible that the poor correlation is due to inaccuracy of TOP-assay data, the TOF data does correlate with TOP-assay the uncertainty in the XPS data is more likely. However, it may be useful for comparing components for some material types. For example, when just evaluating stainless steel components, the r^2 of fluorine mass and fluorine surface percentage increases to 0.67. Components from foam system had significantly greater percent fluorine (Kruskal Wallis Test; $p<0.0001$) than components from the mixed or water systems, which is consistent with pre- and post-TOP assay and TOF data.

Although plastic components appeared to have a greater percentage of fluorine relative to SS and brass components, there were no statistically significant differences observed. Since XPS is reported on a relative scale rather than absolute this is likely due to differences in fluorine having a smaller on-surface composition relative to other elements (e.g., carbon, nitrogen, copper).

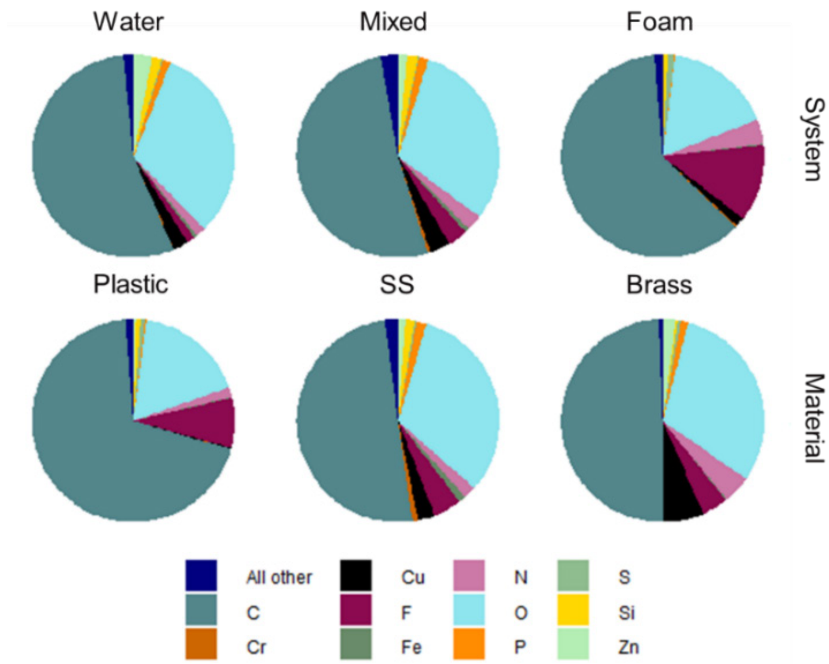

Figure 6. XPS Concentrations on Various Components Removed from the ARFF Vehicle Following a Triple Water Rinse of the Fire Suppression System.

Figure excludes components that were analyzed after methanol extraction.

XPS may be useful for evaluating PFAS extraction efficiency. A reduction in surface fluorine post-extraction can give an estimate of how effect the removal of PFAS was. For example, part 48, which was a hose in the mixed system that had the greatest PFAS mass of all components, was sent for XPS analysis pre- and post MeOH extraction. The percent fluorine decreased from 21.6% to 1%, indicating that >95% of the surface fluorine was successfully removed. While XPS may not always directly reflect PFAS concentration in different material types within ARFF systems, its ability to analyze surface fluorine composition offers insights into PFAS distribution and extraction efficiency. For practitioners of foam transitions, XPS may enhance understanding of surface contamination, optimizing cleaning protocols, and developing targeted strategies for mitigating PFAS risks in ARFF operations.

6.4 ARFF APPARATUS REASSEMBLY AND REBOUND CHARACTERIZATION

The results of the ARFF apparatus reassembly and characterization are demonstrated in Anderson et al. (submitted 2024). The final rinsing event conducted after the new components were installed were significantly reduced (>99%) compared to the baseline rinsing event (**Table 3**). However, there were low level PFAS concentrations in samples from both the foam only and water only portions of the ARFF vehicle. The presence of PFAS in the post-reassembly rinse identifies the likelihood that PFAS is present in the system component manufacturing process.

This presence may be intentional or not, as PFAS could be included as part of the manufacturing process, as a manufacturing aid, or may be present in common production areas. Like in the baseline rinsing event, there was PFAS detected in the water blanks. The total PFAS concentration found in the water blanks ranged from 5-20% of the concentration in the water and foam system samples both pre- and post-TOP assay, so concentrations reported for those samples are slightly overestimated. A rebound characterization was not possible because the vehicle was decommissioned prior to completion of the project.

7.0 COST ASSESSMENT

This section provides cost information for operational costs of the rinsing, disassembly, and replacement process to aid in establishing realistic costs for implementing the technology and comparing it to potential alternative technologies. Sections are provided for each of the key cost elements tracked and documented during the demonstration.

7.1 COST MODEL

The cost estimate for the total replacement of an ARFF on-board fire suppression system, including the disassembly, new components, and reassembly is approximately $374,000 (**Table 5**). There are additional labor costs associated with the disassembly/inventory of components (approximately 200 people hours), for which a DoD labor estimate in terms of cost is unavailable.

Table 5. Cost Model for Foam System Replacement

Cost Element	Data Tracked During the Demonstration	Costs
TRANSPORT OF ARFF APPARATUS TO/FROM DISASSEMBLY LOCATION	• Labor • Transportation costs	Labor and transportation costs were not provided by DoD*
DISASSEMBLY AND PRELIMINARY WATER FLUSHING	• Personnel required and associated labor	Arcadis spent approximately 200 person-hours for the disassembly and inventory of components
PART PROCUREMENT AND REPLACEMENT	• Materials • Labor required to find and purchase appropriate components • Labor and expertise required for part replacement	Total material costs for part replacement were $263,626.84 Labor hours were not proved by DoD*
EQUIPMENT DOWNTIME	• Opportunity cost of taking the ARFF apparatus out of commission for the demonstration period	While this information is unavailable due to missing components, the truck was out of commission for 15 months without completion

* Itemized labor costs were not provided by DoD, but the total labor costs provided for the foam system replacement is $110,502.58

7.2 COST DRIVERS

Anticipated cost drivers that should be considered in selecting approach for future implementation are the cost and availability of components required for replacement, the labor hours required for disassembly of either all components or a subset of components, and the costs associated with the downtime of the vehicle for maintenance. The model and year of the ARFF apparatus will impact the costs associated with component replacement. For example, some of the components for the current foam system were custom manufactured or required special orders, which generally cost more than components that are more commercially available.

7.3 COST ANALYSIS

Alternatives to a complete replacement of fire suppression system would be cleaning the fire suppression system, acquiring a brand new ARFF apparatus as previously demonstrated under ER20-5364, or selectively replacing critical components within the system known to have greater PFAS mass loadings. As discussed, the cost to replace all components within the current foam system, including labor and materials, is approximately $374,000. Most of that cost is due to materials, which would be significantly reduced by targeted a subset of critical components for replacement (e.g., hoses, tanks). As previously stated, for the vehicle investigated in this study, replacing 5 components could be replaced to result in a 90% removal of PFAS. These parts included two rubber hoses from the mixed system, one brass valve from the foam system, the plastic water tank, and a stainless-steel part from the foam stem. The exact cost could not be determined, both because the itemized costs for parts were not provided and the time and labor costs for dismantling and replacing just a subset of parts could not be estimated.

8.0 PERFORMANCE ASSESSMENT

The following summarizes data analysis in support of the assessment of performance objectives, with a subsection for each performance objective.

8.1 PERFORMANCE OBJECTIVE: PART-BY-PART TOTAL REPLACEMENT COSTS OF WETTED COMPONENTS OF ON—BOARD FOAM SYSTEM

This objective examined the level of effort required to replace all internal PFAS-containing components of the ARFF apparatus. The cost model is summarized in **Section 7** above including information on the total cost for materials and labor provided by the DoD and the additional number of labor hours required for part disassembly and inventory management (**Table 4**). Itemized costs for components and labor sorted by task were not proved by the DoD. *The Success Criteria was partially met, with the total costs associated with ARFF apparatus part replacement being quantified at $374,000. A time estimate was unavailable for this project due to missing components, resulting in the truck being out of commission for 15 months without completion.*

8.2 PERFORMANCE OBJECTIVE: CHARACTERIZATION OF PFAS IMPACTS ON ARFF APPARATUS ON-BOARD FOAM SYSTEM COMPONENTS

This objective was designed to determine the extent of PFAS and organic fluorine impact on components of the ARFF apparatus on-board foam system after a triple water rinse. Analyses were used to establish which components are most impacted by PFAS to help understand component replacement vs flushing. The PFAS distribution on each component was evaluated at the bench scale based on the average mass of PFAS removed per wetted surface area. *This Success Criteria was met, with the total mass of PFAS per wetted surface area on each system component calculated. The total mass of PFAS for the whole system was 44 mg measured pre-TOP assay, and 120 mg measured post-TOP assay (**Table 3**). Components within the mixed and foam systems had significantly greater residual PFAS than components within the water-only system, and components made of rubber and brass had greater PFAS than components made of other materials (e.g., stainless steel).*

8.3 PERFORMANCE OBJECTIVE: QUANTIFICATION OF THE IMPACT OF TOTAL SYSTEM REPLACEMENT ON PFAS CONTENT IN FOAM SYSTEM AFTER WATER RINSE

This objective was designed to determine the effectiveness of replacing all wetted ARFF apparatus on-board foam system components for removing PFAS from the system. Analyses of water rinsate and ex-situ component analysis were used to characterize the extent of PFAS impacts on the system. *The Success Criteria was not deemed successful, with both the rinsates from the water and foam system having total PFAS concentrations exceeding 70 ng/L (Pre-TOP: 87.7-141 ng/L; Post-TOP: 147-318 ng/L). While the Criteria was unsuccessful, these results indicate that since PFAS are present in an ARFF system with new components, a complete replacement of components may not be necessary, and instead just replacing components with the greatest PFAS mass loading may be suitable.*

8.4 PERFORMANCE OBJECTIVE: ARFF APPARATUS MONITORING

This objective was designed to define the long-term effectiveness of total foam system replacement by monitoring PFAS concentration in replacement foam (or surrogate agent). Analyses will be used to establish the existence of rebound PFAS concentrations in replacement foam. Replacement foam (or foam surrogate agent) will be analyzed to obtain speciated PFAS, TOC, and TOF concentrations. Replacement foam will be analyzed three times after installation of replacement foam (or foam surrogate agent). The collection times will be identified by the project team and ESTCP.

The primary goal is the minimization of PFAS concentrations in foam installed after changeout. Acceptable levels of PFAS will be dependent upon the specific application and regulatory framework; however, for the purposes of this project, concentrations above 10 µg/L of total PFAS in the newly installed foam indicate significant rebound of PFAS from system surfaces into the foam. Therefore, the Success Criteria will be met when analyses of replacement foam determine that total PFAS concentrations are at or below 10 µg/L.

This performance objective was unable to be evaluated due to the apparatus being decommissioned prior to completion of this project.

9.0 IMPLEMENTATION ISSUES

Implementation issues included obstacles in acquiring replacement components for the ARFF system, such as out-of-stock components, leading to significant delays. Additionally retrofitted components complicated the inventory and installation process. It is acknowledged that, as a pilot project, there were additional difficulties in acquiring individual parts that needed to be custom manufactured increasing costs and lead times for parts that, if part of a larger program of replacement, could see reduced individual part costs and more advantageous lead times. The challenges associated with acquiring new components resulted in the truck sitting out of service for 15 months before being decommissioned, making a rebound test impossible.

Numerous analytical challenges were encountered during the ARFF baseline rinse and the component characterization. These challenges include high detection limits, making it difficult to accurately measure PFAS concentrations. Because PFOS and 6:2 FtS were in general so much greater in concentration than other PFAS, high dilution factors were required and compounds that were present at lower concentrations often resulted in estimated data. The total PFAS concentrations were likely unaffected because it was dominated by a handful of compounds, but there were limitations in terms of PFAS contribution profiles.

Another analytical issue that was encountered with poor oxidating of some TOP assay samples. At best, this resulted in re-extraction and extended turnaround times, and at worst resulted in an underestimation of PFAS due to insufficient sample size for re-extraction. This primarily impacted the baseline flush samples, and the total concentrations measured there are likely underestimated, the extent of which is uncertain. In general, turnaround times for Method 1633 were significantly greater than expected, and in some cases exceeded 10 months for a single set of submitted samples.

Alternative extraction methods were required for components that were too large to be extracted by other methods. Methanol wipe extractions were used because of the success in previous projects, but in the current project they resulted in poor extraction recoveries. The total PFAS mass for the components extracted by methanol wipes were likely underestimated. The total PFAS mass reported was underestimated as a result of this, but this effect was mitigated by the fact that only a small number of components could only be extracted by wipes. While wipe extractions have shown effectiveness in the past, the recent challenges emphasize that their suitability may vary depending on the material being analyzed.

10.0 RECOMMENDATIONS

The execution of this project has provided a unique opportunity to view the complexities of managing a foam transition process. Specific to this project is the goal to completely replace the wetted system inside a vehicle to remove PFAS and prepare the vehicle to operate without PFAS contamination derived from AFFF. As was observed from characterization of parts removed from the ARFF apparatus, a three times water rinse is not sufficient to remove PFAS from the wetted surfaces of an apparatus in the water or foam systems. Further, with PFAS observed in the post-reassembly rinse process, full replacement of a wetted system may not serve to rid the vehicle of all PFAS since use of PFAS in the manufacturing process or as a manufacturing aid could impart PFAS onto the newly manufactured surfaces of a vehicle. This section serves to provide recommendations related to the work directly performed in this project: replacement of parts to remove PFAS from the wetted surfaces of an ARFF apparatus.

Section 9 provides an accounting of the issues encountered during this project. Relevant to this recommendations section, the obstacles in acquiring replacement components created a significant drag on progress of this project that would serve to deter its full completion. Because of the complexity of a program replacing a full system worth of components, an abbreviated program consisting of replacing a small subset of components that represent approximately 90% of PFAS present in the system would serve to reduce the overall cost and downtime related to transition by focusing the supply chain on a smaller number of parts that could be acquired more quickly. This small list of parts identified in Section 6 of the report are: two hoses from the mixed system, a brass valve from the foam system, the water tank, and a stainless steel part from the foam system.

This report cannot speak to the PFAS content endpoint of replacement of a small subset of parts in combination of execution of a single water rinse, consistent with DoD policy, as data was not generated to address this scenario. However, previous data generated by ESTCP project ER20-5364 demonstrated in a fixed fire suppression system that approximately 80% removal of total PFAS was achievable by a single water rinse. If that removal percentage is consistent with ARFF apparatuses, and removal of the five parts identified in this report may serve to marginally increase that removal efficiency. However, while greater than 80 percent removal of PFAS is a notable amount of mass removed, the remaining approximately 20 percent of PFAS represents an important residual of PFAS left behind that would be expected to be released from system surfaces and into new fluorine-free firefighting formulations, maintaining the DoD's potential liability for release of PFAS into the environment, albeit at a reduced magnitude.

The analytical data presented in this report and the noted implementation issues related to foam transition by full system replacement do not paint a clear picture of success using this method. A three times water rinse of the wetted system after parts replacement showed PFAS present in the rinse water, while extraction of PFAS from parts previously rinsed three times shows presence of PFAS at varying concentrations independent of system location or material of construction.

The data generated in this study does provide information that a partial system replacement coupled with a single water rinse may provide an acceptable alternative to full system replacement for DoD equipment foam transition. With a combined strategy may come additional project challenges that would threaten its viability, including, but not limited to: availability of replacement parts, protracted lead time for identified and unavailable parts, extent of disassembly required to access, remove, and replace identified parts, and the cost of replacement of parts identified.

The single water rinse process is already policy for DoD, which means that waste generated during the rinse process and labor and associated costs for the rinse process are inherent challenges to a combined approach.

The complexity of partial disassembly with single water rinse would require a consistency in procedure to address the location in the sequence of transition where the single water rinse would occur. In a system with partial replacement, there are potential pitfalls with performing that rinse before or after replacement of the identified parts. Firstly, performance of a single water rinse comes with it the assumption that that water rinse will effectively remove AFFF from all wetted surfaces in the equipment. If the single water rinse is not effectively performed, AFFF residual with high concentrations of PFAS that remains in place or is deposited in a different part of the system may impact parts of the system that were not as heavily impacted. AFFF, especially that which is aged in a fire suppression system, is notably reticent to removal, often forming caked, gelled, or otherwise thickened layers within systems. Performing the rinse before replacement of the identified parts leaves the heavily impacted parts in place and may lead to an unintentional redistribution of PFAS within the system from more heavily impacted parts to those that are less impacted. Alternatively, performing the rinse after partial part replacement would subject the newly installed parts to additional PFAS loading dispersed from the previously impacted parts surrounding the new parts.

The extent of the effectiveness of a partial system replacement and single water rinse strategy would require additional work be completed to characterize a system subjected to this treatment process. The results of this study and other work done by the ESTCP program identify important work that can support a hypothesis of partial system replacement with a single water rinse:

1. a pilot study using AFFF-containing piping systems demonstrating the effective removal of AFFF residual in a repeatable rinse process to confirm that a single water rinse will provide effective removal in preparation for partial system replacement
2. a pilot study that addresses the effective removal of a combined rinse and partial replacement strategy, consisting of bench- and field-scale rinsing procedures that identify the effect of the timing of the single water rinse in relation to part replacement. Execution of this pilot study would allow the DoD to determine the feasibility of partial system replacement through supplier and replacement facility coordination.

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APPENDIX B SUBMITTED MANUSCRIPT

ABSTRACT

When fire suppression systems that held aqueous film forming foams (AFFF) are transitioned to per- and polyfluoroalkyl substance (PFAS)-free firefighting formulations, PFAS can dissolve from the wetted surfaces of the systems and release into the new firefighting formulations. The overall objective of this work was to characterize PFAS residual mass on the wetted surfaces of ARFF vehicle on-board fire suppression system components from the water, mixed fire water, and foam concentrate systems with various geometries, materials of construction, and locations within the fire suppression system. The ARFF vehicle components were dismantled from the system after a triple water rinse procedure which removed 19,600 mg total measured PFAS post-TOP assay from the foam concentrate system and 23 mg total measured PFAS post-TOP assay from the water system. Results for total mass of PFAS on each part indicate most of the residuals were present on parts which have large surfaces areas or the rubber or brass parts. For large surface area plastic parts (i.e., foam and water tanks), the overall mass on these parts was greater than other parts even though the PFAS residual concentrations were lower compared to other material types due to larger surface areas for accumulation. Parts constructed of rubber or brass appeared to have higher measured PFAS surface residual concentrations as compared to parts constructed of plastic or stainless steel.

Keywords

PFAS, AFFF, Fire suppression, Foam transition

INTRODUCTION

Aqueous film forming foam (AFFF) is known to contain per- and polyfluoroalkyl substances (PFAS), which are used in these products for their foaming, film forming, and heat resistant properties. AFFF was first developed in the 1960s and was rapidly adopted as a superior alternative to previous protein based foams (Darwin, 2004). In the United States (US), certified airports are required to maintain a minimum number of air rescue and firefighting (ARFF) vehicles carrying aqueous film forming foam (AFFF) and a foam discharge capacity based on their 'Airport Index' (FAA, 2013). Many fire suppression systems, including ARFF vehicles, are impacted by residual entrained PFAS resulting from exposure to AFFF, which has been known to contain >10 g/L of total PFAS (Houtz et al., 2013).

Companies manufacture alternative PFAS-free firefighting formulations (Bioex, 2024; PerimeterSolutions, 2024), and the US Department of Defense (DoD) has published the Military Performance Specification (Mil-Spec) for PFAS free firefighting formulation use on land with fresh water (USDoD, 2023). There are an increasing number of states and countries promulgating regulations around the manufacture, sale, release and/or use of PFAS containing AFFF (Washington, 2018; Colorado, 2019; Allan, 2020; Colorado, 2020; Congress, 2021; Resources, 2022; Alaska, 2023).

PFAS residuals on wetted fire suppression system surfaces has complicated the foam transition process. These residuals have been shown to be present on materials that have been in contact with highly concentrated PFAS-containing materials like AFFF (Lang et al., 2022; Dahlbom et al., 2024).

PFAS are known to self-assemble and coat surfaces at liquid/solid interfaces to form water resistant coatings and can therefore be difficult to fully remove from surfaces. If ARFF foam systems are not properly cleaned prior to replacement PFAS-free firefighting formulation being added, PFAS can dissolve from the surfaces of the system and release into the new PFAS free firefighting formulation (Ross and Storch, 2020). Lang et al. (2022) previously demonstrated that stainless steel AFFF concentrate pipe can amass approximately 10 $\mu g/cm^2$ of measurable surface-associated PFAS (post-TOP assay). Dahlbom et al. (2024) demonstrated almost 100 $\mu g/cm^2$ of measured PFAS surface residuals on galvanized steel AFFF piping, 0.01 to 0.1 $\mu g/cm^2$ on an AFFF concentrate tank, almost 1 $\mu g/cm^2$ on a handheld fire extinguisher, and almost 10 $\mu g/cm^2$ on a fire hose (post-TOP assay) (Dahlbom et al., 2024).

The overall objective of this work was to characterize PFAS residual mass on the wetted surfaces of ARFF vehicle on-board fire suppression system components from the water, mixed foam, and foam concentrate systems with various geometries, materials of construction, and locations within the fire suppression system. ARFF vehicles typically have both a tank containing water and a tank containing AFFF concentrate. When foam is needed, the water and foam are piped to a proportioner where they are mixed at the appropriate ratios. Mixed foam is then piped to a variety of turrets or outlets for handlines. A more complete understanding of the extent of PFAS impacts in an on-board fire suppression system will provide information to determine the best course of action to achieve a substantially PFAS-free system and prevent future release to the environment.

MATERIALS AND METHODS

ARFF Vehicle Baseline Water Rinsing

This study was conducted on an Oshkosh T-1500 with a 210-gallon plastic foam tank and 1,500-gallon polypropylene water tank located at Red River Army Depot (RRAD) in Texarkana, Texas. The fire suppression system on the ARFF vehicle contains three distinct zones: water supply "water", foam concentrate only "foam", and mixed fire water "mixed" (**Figure S1 and Table S1**). Prior to removal of any components, a series of three water rinses were conducted on the water side and foam concentrate portions of the fire suppression system. Water rinses were intended to flush out existing PFAS residue and characterize water-soluble PFAS impacts within the ARFF apparatus. Due to the system configuration, water rinsing could not be conducted on the mixed fire water portion of the ARFF vehicle (**Table S1**).

The total volume for each rinse was 225 gallons for both the foam concentrate and water portions of the ARFF apparatus in the baseline and final events. For the baseline event, the first water rinses were loaded into the water and foam tanks separately and left in place overnight. The next day the baseline water rinse was passed through the respective water only or foam only portions of the ARFF vehicle and drained into high-density polyethylene (HDPE) totes for sampling. Due to a leak in the ARFF vehicle foam system, only a partial rinsing (soaking) was completed for some sections. **Table S1** demonstrates which components were included in the baseline water rinse. PFAS concentrations were measured in these baseline water rinses to determine if there were PFAS impacts on the portion of the system not known to be in contact directly with AFFF. The PFAS concentration from the foam concentrate system was measured after each rinsing event to provide information on water rinse effectiveness and efficiency.

For each rinse step of both the water and foam systems, a dedicated clean water pump and hose assembly was used to load potable water sourced from a faucet located in the shop. A sample of the water from the faucet was collected for PFAS analysis. The clean water was staged in new containers, with a single container dedicated to each rinse step. Once the water was loaded into the apparatus, the clean water pump and hose assembly were replaced, and all subsequent liquid transfer was performed by an inline pump as part of the recirculation manifold assembly. The rinse water from each step was containerized separately to minimize carryover between rinse steps. In addition, the three water tank rinse steps were performed first, then the three foam tank rinse steps were performed. After completion of recirculation, the rinsate was drained through the recirculation manifold into the rinse-step-specific tote. Sampling was performed from each tote after completion of the rinsate drainage steps.

At each rinse step, water samples were collected from the holding totes in 60 mL HDPE containers (PFAS), 40 mL hydrochloric acid-preserved glass containers (TOC), and 250 mL HDPE containers (TOF). Following sample collection, sample containers were stored on ice and shipped to the analyzing laboratory via FedEx Express shipment. Samples were submitted to SGS AXYS (SGS; Sidney, BC, Canada) for PFAS analysis before and after TOP assay via Method 1633 and total organic carbon (TOC) analysis via Methods SM5310 B-11/SW9060A. A blank sample of the source water used for rinsing was also submitted in duplicate for analysis by TOP assay via Method 1633. PFAS analysis was performed by SGS using liquid chromatography with tandem mass spectroscopy (LC-MS/MS). Single samples from each rinse step were also submitted to Clarkson University for analysis of inorganic fluoride (IF) and total fluoride (TF) using CIC for estimation of TOF.

ARFF Disassembly and Components Collection/Shipment

Following the baseline water rinsing, the on-board foam system was disassembled, and individual system components were shipped to the Arcadis Treatability Laboratory (ATL) in Durham, North Carolina. The ARFF apparatus was systematically disassembled while inventorying the components and preparing the parts for shipping. A schematic of the truck fire suppression system was used to help identify components prior to disassembly. During disassembly, FieldNow™ (digital field asset management tool) was used to catalogue component-specific details and maintain an understanding of where each component fit in the ARFF. As part of documentation, each component was provided a machine-readable symbol (i.e., barcode) for tracking, and all components were photographed prior to and after removal from the ARFF apparatus. Components were prepared for shipping by placing them in individual HDPE bags, labelling the bags, and collecting them in crates for shipping. Field cutting of the foam concentrate and water tank walls and baffles was performed to allow for shipping. Components were stored at room temperature prior to and following shipment. A full component list is shown in **Table S1**, and the components are summarized by material type in **Table 1**.

The ATL received 82 unique catalogued components from the ARFF's on-board firefighting formulation delivery system as well as the foam and water tanks, which were split up into multiple baffles (**Table 1 and S1**). Each component received further review to determine appropriate sub-samples, duplication, and extraction methods. Components that contained multiple material types or geometries were sub-sampled to isolate variables as feasible for a total of 138 subparts. Additionally, components with large, wetted surface areas were extracted in quintuplicate when feasible.

Forty percent of parts were constructed of stainless steel, but there were also several composed of plastic and brass (**Table 1**). There were a variety of geometries including the foam and water tanks, hoses, straight pipes, valves, and elbows (**Table S1**).

Table 1. Component Pieces Removed from ARFF Vehicle (Full component list in Supplemental Information – Table S1)

Material Type*	Water System	Mixed System**	Foam System	Dry Chemical**
Plastic	12	1	12	0
Brass	10	15	8	1
Stainless Steel	15	22	18	1
Hose	1	11	0	1
Aluminum	4	0	0	0
Mixed	1	2	2	0
Carbon Steel	0	1	0	0
Total	**43**	**52**	**40**	**3**

*All material types assumed based on visual observation

**Mixed system and dry chemical not included in baseline rinsing event

Component Processing and Surface Characterization

To assess the residual PFAS surface concentrations on each component, destructive sampling (e.g., cutting and solvent extraction) was employed on applicable components including the tanks, hoses, and piping using methods from Lang et al. (2022). This destructive sampling method for PFAS surface content analysis was selected unless one of the following criteria was met: (a) the material was shown to be unstable when exposed to a methanol-based extraction solution (e.g., 95% methanol, 5% deionized water) over 24 hours in a compatibility pre-test performed on all non-metal materials tested; (b) the exterior of the component was painted or deemed dirty enough to potentially interfere with analytical instrumentation or potentially contaminated with PFAS; or (c) the component was deemed unable to be cut safely with the tools available (e.g., pumps, turrets, and some valves).

To assess the residual PFAS surface concentrations on the components deemed unsuitable for destructive sampling, cap and fill sampling or wipe sampling was performed. If a component had Victaulic ends on both sides but was unable to be destructively sampled, it was sampled using a cap-and-fill method. Otherwise, the component was extracted and analyzed via a wipe sampling method. Full details of extraction methods are in the SI. All MeOH and wipe extracts were sent to SGS for PFAS analysis before and after TOP assay via Method 1633. In addition to PFAS analysis, a subset of MeOH extracts were went to PACE for TOF analysis.

Elemental Surface Content – XPS

A subset of parts (n = 58) was selected for X-ray photoelectron spectroscopy (XPS) analysis to include a representative sample of system location and material (**Table S1**). The majority of subpieces of parts were sent for XPS analysis pre-MeOH extraction, but a hose from the mixed fire water system was measured before and after MeOH extraction. There were two parts that had insufficient material remaining after extraction, and thus they were sent for XPS analysis post extraction.

XPS was performed by Surface Science Western (SSW) using a Kratos AXIS Supra X-ray photoelectron spectrometer. XPS can detect all elemental deposits, except hydrogen and helium, by probing the surface of the sample to a depth of 7–10 nanometers (nm), and has detection limits ranging from 0.1–0.5 atomic percent (%) depending on the element.(Shard, 2014) The survey scan analyses were carried out with an analysis area of 300 µm × 700 µm and a pass energy of 160 eV.

Wetted Surface Area Measurement

To standardize measured PFAS and fluorine concentrations across methods and component types, all results were normalized to the component surface area measured by each individual method. Manual measurements of extracted component wetted surface areas were conducted with measurement tapes as well as electronic angle finders and electronic callipers. Three dimensional scans were conducted using the handheld EinScan HX scanner and processed by RZA Technologies. Some components were scanned both whole and disassembled or cut to facilitate accurate wetted surface area models. Hand measurements were used to provide quality assurance and control process for the scans. Hydraulic hoses were excluded from the scanning procedure.

Statistical Analysis and Data Processing

Method 1633 pre- and post TOP-assay results for components are provided in supplemental data tables (Tables S5 and S6, respectively). All PFAS concentrations above reporting limits but below their limits of quantification (LOQ) were substituted with their corresponding limit of detection (LOD). If a PFAS was below LOD, it is listed as "< LOD", where "LOD" is specified for each sample/PFAS. The total mass of PFAS for each part was calculated using the extract concentration and volume, the wetted surface area, and the total part surface area. For comparison of final data, Kruskal-Wallis H tests were used to evaluate whether there were statistical differences among the nonparametric data.

ARFF Vehicle Reassembly and Final Rinsing

RRAD personnel acquired and replaced wetted parts for the fire suppression system in the ARFF vehicle with the objective of analyzing PFAS impacts on an entirely new system. Procurement of parts took more than one year due to the age and complexity of the system and parts that required custom fabrication for the ARFF vehicle. Following procurement of new replacement parts for the fire suppression system on the ARFF vehicle, Arcadis re-mobilized to RRAD to perform a series of final water rinses on the water and foam portions of ARFF apparatus. Due to the system configuration, final water rinsing could not be conducted on the mixed fire water portion of the ARFF vehicle.

The general approach for each rinse step was the same as for the baseline rinsing event except that each rinse was not left to soak overnight, instead water was recirculated for three hours, and then drained to a dedicated container. Water used for rinsing was at ambient temperature and sourced from RRAD's potable water system. For this event, 195 gallons and 210 gallons were used for each rinse of the water and foam systems, respectively.

A sample of the water from the faucet was collected for baseline PFAS analysis. The clean water was staged in new totes, with a single tote dedicated to each rinse step. Once the water was loaded into the apparatus, the clean water pump and hose assembly were replaced and all subsequent liquid transfer was performed by an inline pump as part of the recirculation manifold assembly.

The rinse water from each step was containerized in dedicated waste containers to minimize carryover from one rinse step to the next. The recirculation pump and manifold shared common piping through which all rinsate passed. Flow was isolated to each step's dedicated piping and storage, to minimize the potential for cross-contamination. Sampling was performed from each container after completion of the rinsate drainage steps. Black shavings were observed in all post-recirculation rinsates. These shavings were not observed in the clean water fill system and are expected to have been generated from the manufacturing and installation of the new tank assembly.

At each rinse step, triplicate water samples were collected from the holding totes in 60 mL (Post-TOP assay) and 250 mL (Pre-TOP assay) HDPE containers. Following sample collection, sample containers were stored on ice until all rinsing steps were completed. All samples were then shipped to the analyzing laboratory via FedEx overnight shipment. A blank sample of the source water used for rinsing and one duplicate sample were also submitted for analysis by Pre-TOP and Post-TOP assay via Method 1633. The water blank was on-site clean potable water collected from the tap used to supply rinse water. PFAS analysis was performed by SGS using liquid chromatography with tandem mass spectroscopy (LC-MS/MS). A field blank sample of the source water used for rinsing and two equipment blanks were also submitted for analysis by TOP assay via Method 1633 in duplicate. The field blank was on-site clean tap water collected from a clean tote, collected by pouring clean tap water (from the tap water spigot) into a sample container and letting it sit on-site with the other samples. The equipment blanks were collected from the water supply hose and pump before and after system rinsing.

RESULTS

ARFF Vehicle Rinsing

The mass removal for each rinse was calculated as the measured concentration multiplied by the rinsing volumes. During the baseline water rinsing event, 1,020 mg total measured PFAS pre-TOP assay and 19,600 mg total measured PFAS post-TOP assay was removed from the foam only portion of the system (**Table 2**). The water system also contained PFAS, although to a lesser extent (1.7 mg pre-TOP assay and 23 mg post-TOP assay). While these results indicate PFAS impacts extend to the water system in addition to the foam concentrate and mixed portion of the system, the measured mass removals are less than 1% of the measured mass removed from the foam only portion of the system during the baseline water rinse. The water blank sample demonstrated short chain PFCAs in the post-TOP assay sample and PFOS/PFBA in the pre-TOP assay sample at concentrations in the same range as samples from the water only system rinsing (**Table S2**). However, the total mass of PFAS in the blank water sample was 2% of the total mass found in the water only system pre-TOP assay and 24% of the total PFAS mass post-TOP assay, indicating that most of the contamination present is due to precursors. Thus, PFAS observed in the water only system rinsing is attributed to the system itself, although the post-TOP assay concentrations may be slightly inflated by the water used in the rinsing.

The presence of PFAS in the water system rinse is of interest because AFFF is not intentionally added to the water system during normal operations. The most likely reason for PFAS in the water system rinse is that there was backflow of small volumes of foam from the proportioner into the water tank. This is speculated to be a result of faulty check valve, which is designed to prevent the backflow of fluids in foam systems. When a faulty check valve is present in the system, it may allow water with PFAS residues from previous operations to backflow into the water system during routine maintenance or testing procedures. The PFAS profiles among the water and foam system further support this pathway (**Figure S1)**. The largest contributor to the total PFAS signature in the pre-TOP assay samples for the foam system was PFOS (68% of total PFAS mass), followed by 6:2 FtS (16%) and PFHxS (7.5%). In contrast, the water system was dominated by 6:2 FtS (40%) followed by PFOS (27%) and C4-C10 PFCAs (19%). A likely explanation for the higher proportion of 6:2 FtS in the water system rinse is that as the check valve degraded or malfunctioned over time, it would have allowed greater backflow of the more recently used fluorotelomer-based AFFFs than of historically used PFOS-based AFFFs.

There were low level concentrations of 6:2 FtS present in post-TOP assay samples indicating the samples may not have been completely oxidized (**Table S2**). Notably, 6:2 FtS in the first foam rinse had 54% remaining unoxidized, likely due to the large magnitude of precursors present. No remaining sample was available for reanalysis, so the PFAS concentrations in the TOP samples are potentially underestimated. After TOP assay was performed on samples, over 90% of the observed PFAS were short-chain (C7 or below) PFCAs.

Table 2. ARFF Vehicle Rinsing Event Results.

Individual PFAS concentrations for each rinse in the baseline and final rinsing events are demonstrated in the Supplemental Information Table S2.

			Total Measured Mass Removed (mg)*			
			Rinse 1	**Rinse 2**	**Rinse 3**	**Total**
Baseline Event	**Water System**	**Pre-TOP**	0.67	0.57	0.44	1.7
		Post-TOP	2.4	13	7.8	23
	Foam System	**Pre-TOP**	930	78	8.8	1020
		Post-TOP	19000	510	55	19600
Final Event	**Water System**	**Pre-TOP**	0.020**	0.021	0.024	0.065
		Post-TOP	0.029	0.032	0.047	0.108
	Foam System	**Pre-TOP**	0.035	0.033	0.045	0.113
		Post-TOP	0.089	0.092	0.072	0.253

* Total measured mass removed calculated as the sum of the PFAS concentrations in the bulk rinsing water times the volume of rinsing water (**Table S3**)

**Final event masses demonstrated as the sum of the average individual PFAS concentrations

The final rinsing event conducted after the new parts were installed demonstrated low level PFAS concentrations in samples from both the foam only and water only portions of the ARFF vehicle (**Table S2**). Like in the baseline rinsing event, there was PFAS detected in the water blanks. The total PFAS concentration found in the water blanks ranged from 5-20% of the concentration in the water and foam system samples both pre- and post-TOP assay, so concentrations reported for those samples are slightly overestimated.

The TOF concentrations in the samples from the foam only portion of the system demonstrate approximately 20 g of total organic fluorine was removed during the baseline rinsing event. While the total measured post-TOP assay concentrations were higher, the TOF and post-TOP assay data demonstrate similar masses of PFAS (e.g., in the range of grams) were removed from the system.

For the baseline rinsing event, the trip blank and water blank demonstrated TOF concentrations of 0.64 and 0.434 mg/L, respectively, indicating the water used for rinsing may have contained PFAS (**Table S3**). While blank TOF concentrations were relatively high, they were less than 3% of the TOF found in the foam rinse. The final rinsing event did not have a water blank sent for TOF analysis, but a trip blank demonstrated TOF concentrations of 0.004 mg/L, which was a significant reduction from the baseline rinsing event.

Component PFAS Loading

PFAS and TOF Surface Concentrations - Destructive Sampling, Cap/Fill, and Wipe Sampling

The pre- and post-TOP assay Method 1633 results for the destructive sampling, cap/fill sampling, and wipe sampling are presented in **Tables S4 and S5**, respectively. The results were converted to the mass of PFAS per wetted surface area using the extraction volumes and extracted surface areas for the destructive and cap/fill methods or the wiped surface area for the wipe method (**Tables S4 and S5**). The total measured post-TOP assay concentrations on individual parts ranged from 0.0001 $\mu g/cm^2$ to 62 $\mu g/cm^2$ (**Table S5**). These concentrations are within the range of previously reported PFAS concentrations on AFFF impacted infrastructure (Lang et al., 2022; Dahlbom et al., 2024).

The total PFAS mass on each part was calculated based on the measured surface concentrations and the total surface area of the part. The total measured PFAS mass in each ARFF vehicle system was then calculated as the sum of the PFAS masses on each part in the system using both pre- and post-TOP assay data (**Table 3**). For all of the residual PFAS part extraction measurements, the pre-TOP assay concentrations were lower than the post-TOP assay concentrations indicating the presence of unmeasured precursors. For the foam system, the total residual PFAS mass measured with pre- and post-TOP assay (18 mg and 51 mg, respectively - **Table 3**) was orders of magnitude lower than the mass removed with rinsing (1,020 mg and 19,600 mg, respectively - **Table 2**), indicating that the baseline rinse was able to flush out AFFF and some self-assembled PFAS.

Table 3. Total Mass of PFAS Residual Measured on Parts Removed from Each Section of the ARFF Fire Suppression System.

	Pre-TOP Total Mass (mg)	Post-TOP Total Mass (mg)
Water System	1.5	2.6
Mixed System	25.0	62.0
Foam System	18.0	51.0
Total	44.0	120

Wipe extractions were performed on parts that were too large and could not be cut down to a smaller size for a destructive or cap/fill extraction. A subset of parts were split and extracted by both destructive and wipe methods for method comparison. Conducting wipe extractions on oversized parts resulted in a significant underestimation of PFAS mass, representing on average only 6.7%

compared to destructive methods. Previous studies have reported good agreement between wipe extractions and typical methanol extractions (Lang et al. 2022), but the discrepancy reported here indicates that wipes may not be a suitable alternative for all material types. Parts solely analyzed through wipe extractions were omitted from detailed statistical analysis due to the method's limitations in accurately quantifying PFAS on part surfaces. Despite this underestimation, the aggregate mass from wipe extractions was factored into the overall mass of the system (**Table 3**).

On average, parts originating from the water system exhibited lower pre-TOP PFAS mass than those from the mixed and foam system. However, longer-chain compounds like PFTeDA were greater in abundance in the water system than the mixed or foam systems, which is likely due to their greater hydrophobicity and thus increased partitioning onto the surface. The two most prominent PFAS across all parts were PFOS and 6:2 FtS, comprising of at least 60% of the total PFAS mass regardless of system and material type (**Figure 1**). The proportion of PFOS and 6:2 FtS on parts in the water and foam systems are consistent with what was observed in the baseline rinses for each system. Foam system parts had the greatest percent contribution of PFOS among systems (53.7%), with the percent PFOS decreasing in the mixed system and at the lowest in the water system.

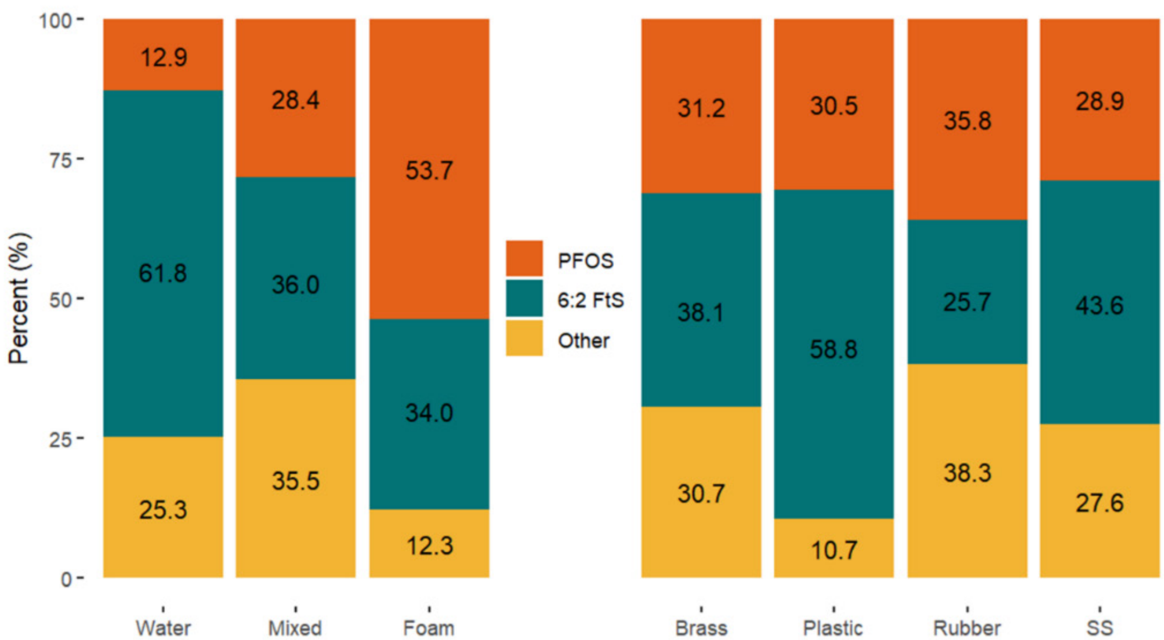

Figure 1. Distribution of PFAS the Two Most Dominant PFAS, PFOS and 6:2 FtS, and All Other Summed PFAS Measured Pre-TOP Assay for Each System and Material Type.

Surface post-TOP assay concentrations were evaluated for parts based on system origin (water, mixed, or foam), the part material (e.g., plastic, brass), and the part shape (bent vs. straight). A Kruskal-Wallis H test resulted in a significant difference ($p < 0.001$) among material types, with a Post-Hoc Dunn's test indicating that parts in the foam and mixed systems both have significantly greater post-TOP PFAS surface concentrations than parts in the water system. The same test found that there was also a statistically significant difference ($p < 0.001$) between different material types, with rubber and brass parts having greater post-TOP PFAS surface concentrations than stainless steel and plastic parts. No statistically significant differences were observed among part shapes.

In general, there was strong agreement (R2 = 0.8831) between TOF and post-TOP assay PFAS mass loading onto part surfaces (**Figure S2**). There were two parts that were removed as statistical outliers: 29A (**Table S1**; a brass valve in the foam system) and 48A (**Table S1**; a hose in the mixed system). These two parts had the greatest total post-TOP PFAS mass of all parts (**Table S6**) and the large dilution factors required for TOF analysis likely contributed to the error in measurement.

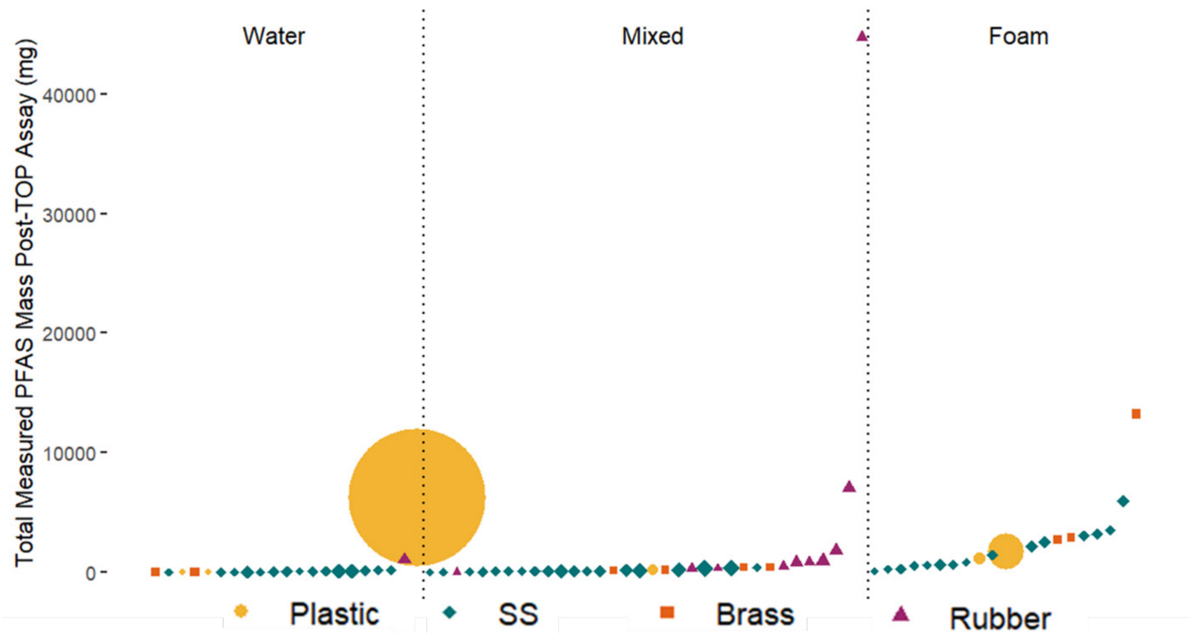

Figure 2. All Truck Parts Listed in Ranked Order from Lowest Total PFAS Mass to Greatest for Each System, with Marker Diameters Scaled to the Part Surface Area

(larger = higher surface area).

The total measured residual PFAS mass on individual parts of the water, foam, and mixed fire water system removed from an ARFF vehicle are shown in **Figure 2**. Results are presented as total mass of PFAS on each part instead of PFAS concentrations in the extractions. Most of the residuals were present on parts which were in the mixed and foam systems (**Table 3**), with rubber and brass parts having the greatest PFAS mass. In general, surface area of parts had minimal contributions to the total mass, indicating that the PFAS residual concentrations were more important to the total PFAS mass present on each part. The notable exception to this conclusion were the foam and water tanks, which had surface areas that were orders of magnitude greater than the other parts. For large surface area plastic parts (i.e. foam and water tanks), the overall mass on these parts was larger than other parts even though the corresponding PFAS residual concentrations were lower compared to other material types (**Table S4**).

Elemental Surface Content - XPS

Surface fluorine composition ranged from 0-30% for individual parts (**Figure 2**, **Table S7**). There was poor correlation between fluorine composition and total PFAS mass pre- or post-TOP assay ($r^2 < 0.3$), so XPS is not considered a viable proxy for PFAS concentration, particularly when comparing different material types. However, it may be useful for comparing parts of the same material type. For example, when just evaluating stainless steel parts, the r^2 increases to 0.67.

Parts from foam system had significantly greater percent fluorine (Kruskal Wallis Test; $p<0.0001$) than parts from the mixed or water systems, which is consistent with pre- and post-TOP assay and TOF data. Although plastic parts appeared to have a greater percentage of fluorine relative to SS and brass parts, there were no statistically significant differences observed. Since XPS is reported on a relative scale rather than absolute this is likely due to differences in fluorine having a smaller on-surface composition relative to other elements (e.g., carbon, nitrogen, copper). Finally, XPS may be useful for evaluating PFAS extraction efficiency.

A reduction in surface fluorine post-extraction can give an estimate of how effect the removal of PFAS was. For example, part 48 (**Table S1**), which was a hose in the mixed system that had the greatest PFAS mass of all parts (**Figure 1**), was sent for XPS analysis pre- and post MeOH extraction. The percent fluorine decreased from 21.6% to 1%, indicating that >95% of the surface fluorine was successfully extracted. While XPS may not always directly reflect PFAS concentration in different material types within ARFF systems, its ability to analyze surface fluorine composition offers insights into PFAS distribution and extraction efficiency. For practitioners of foam transitions, XPS may enhance understanding of surface contamination, optimizing cleaning protocols, and developing targeted strategies for mitigating PFAS risks in ARFF operations.

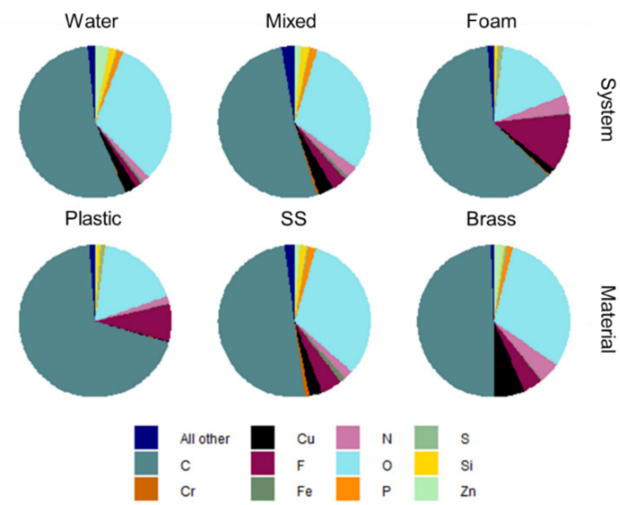

Figure 3. XPS Concentrations on Various Components Removed from the ARFF Vehicle Following a Triple Water Rinse of the fire suppression system; figure excludes parts that were analyzed after methanol extraction.

CONCLUSIONS

The presence of PFAS in the water system in addition to the mixed and foam systems suggests the possibility of cross contamination between these systems. This cross contamination can lead to unintended dispersion of PFAS into areas where they were not intentionally used, potentially exacerbating contamination levels. While there were PFAS residuals on the parts after a full system rinse, the total mass remaining is less than 1% of the mass removed from the foam-only portion of system during the baseline water rinse (120 mg PFAS residuals on parts vs.19,600 mg of PFAS flushed out of system during baseline water rinse). In some cases, rinsing the system alone without any part replacement may be deemed acceptable. However, with increasing regulatory scrutiny, residual PFAS on parts may need to be addressed in the future.

A complete replacement of all parts may not always be a viable option, in which case a strategy to prioritize critical parts for replacement is needed. By targeting and replacing critical parts known to contain high quantities of PFAS or serve as major PFAS reservoirs, substantial reductions in overall PFAS can be achieved. For the current system evaluated, replacing just three specific elements (two hoses and one valve) would result in a 50% decrease in PFAS mass. Expanding this approach to include other critical components like the water tanks and parts within the foam system would result in greater than 90% of the total PFAS mass reduction. This tactic not only offers a cost-effective alternative to comprehensive system replacements, but also allows for the optimization of PFAS contamination efforts for foam transitions and enhances operational sustainability.

Acknowledgements

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SUPPLEMENTAL INFORMATION

PFAS Surface Concentrations – Destructive Sampling

The first step in the destructive method was to cut components into sub-pieces which allowed for complete submergence in the extraction media and optimized the ratio of extraction media to wetted component surface area. The process of creating the coupons varied by material type and size.

Metal components with diameters greater than 4 inches or with unique geometries were first cut with a reciprocating saw into pieces that would fit underneath the chop saw safely. Then, the pieces were cut to the height of the appropriate jar and bisected using the chopsaw. The pieces were then flattened using bench vise and wrench or a hydraulic press. Those pieces were then cut into coupons of a reasonable width using the chop saw. The coupons were measured for surface area using electronic callipers before being arranged for extraction.

Hydraulic hoses were first cut to length of the appropriate jar using a band saw and then bisected using a Dremel with appropriate blades for each layer's material until all but the innermost layer could be peeled off of the hose by hand. The remaining layer was then measured for surface area using electronic callipers before being arranged for extraction.

Tank baffles were cut into batons using the chopsaw. The batons were then measured for surface area using electronic callipers before being arranged for extraction.

PVC and hard plastic components were put into resealable plastic bags and put into the freezer for at least 12 hours. The components were then brittle enough to be smashed with a hammer. The entirety of the component then went into the extraction jars, removing the need for surface area calculations (given that the surface area of the entire component had already been calculated using the initial measurements and scans), with the exception of any pieces reserved for surface-based analyses.

All shop equipment used was decontaminated between components with a 100% methanol rinse caught with aluminium catch pans. If the equipment surface was unable to be reached with a spray bottle, a brush soaked in methanol was utilized to wipe the surface.

Following cutting, the component sample coupons were arranged in either a 250-milliliter or 500-milliliter glass jar, depending on the optimal length of the coupons for safe cutting while maximizing the surface area to volume ratio possible for the extraction. The target component wetted surface area to extraction volume extraction ratio was 1 cm^2 component wetted surface area/mL of extraction solution. If the surface area to volume ratio was at risk of not being sufficient for data accuracy (i.e. >5 cm^2/mL), inert bulking material (HDPE beads, 1/4 and 1/8-inch diameter) were added as a bulking material to the jars.

Component coupons were extracted using a methanol-based extraction solution (e.g., 95% methanol, 5% deionized water) with sonication at the beginning and end of a 24-hour soaking interval. After the soaking period, methanol was decanted from the sample container and split-sampled for analysis. The extracted components were preserved for surface content analysis.

Following extraction, the methanol sample was analyzed in duplicate using Method 1633 with and without TOP assay by SGS AXYS (Sidney, BC, Canada), as well as subset analyzed with CIC for TOF by Con-Test, a Pace Analytical Laboratory (East Longmeadow, MA). The average of the duplicate of the Method 1633 samples was reported in the supplemental information.

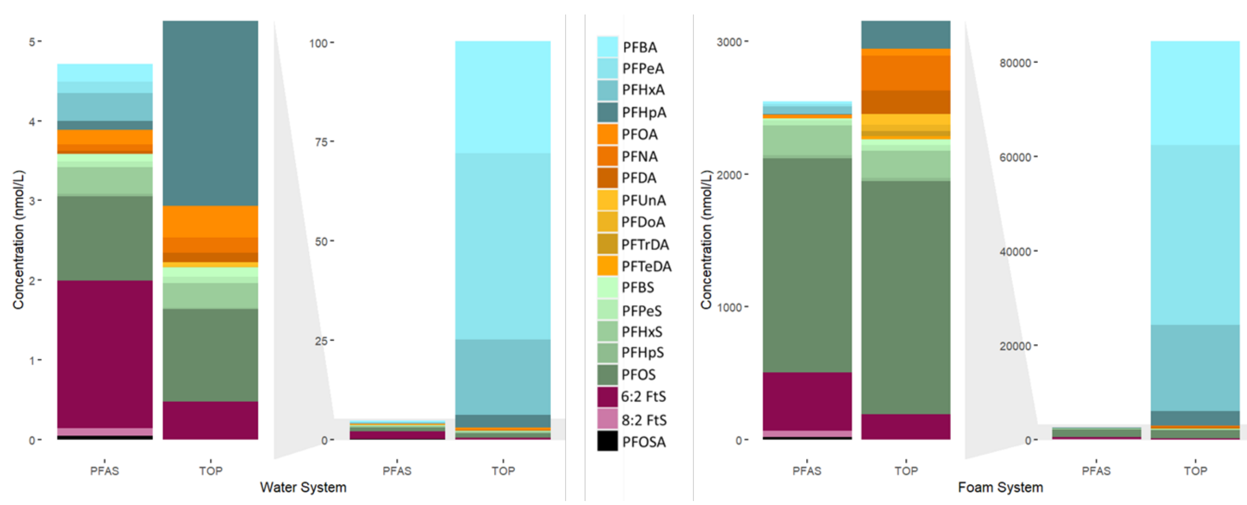
PFAS Surface Concentrations – Cap/Fill

For this non-destructive method, components were filled with the methanol-based extraction solution to provide wetted surface contact. The cap-and-fill method utilized Victaulic clamps and end caps to seal methanol and inert fill material within the component during extraction. The Victaulic fittings were rinsed with methanol before use and between uses. Plugs and caps were rinsed with methanol prior to use. Valves were left in open positions throughout the process due to issues with the inert fill breaking or breaking the valve mechanism. An inert bulking material was added to reduce the volume of methanol-based extraction solution required. The inert fill material was treated as an extractable component for decontamination between uses. After a 24-hour soaking period, the methanol-based extraction solution was drained from the component and analyzed using the methods outlined for samples generated from destructive sampling.

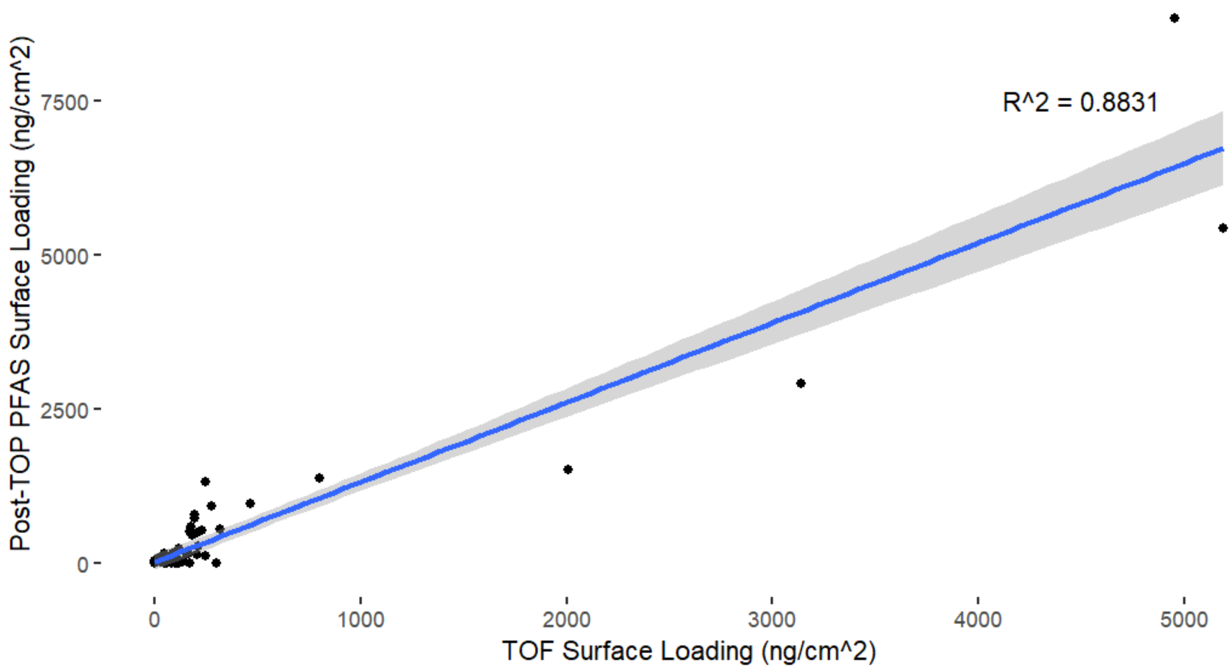
PFAS Surface Concentrations – Wipe Sampling

For components sampled by wipe sampling, SGS provided Advantec GC-50 glass fiber filters which were cut into the 5x5 in squares and then baked before being shipped to the ATL. The wipes provided by SGS AXYS were precut into 5x5 cm squares. The material being wiped was taped off with PTFE-free tape, with surface area measured prior to wiping. 100-500 µL of methanol was aliquoted onto the surface of the taped pipe sample, then the wipe was dabbed on the surface of the methanol and allowed a contact time of at least 30 seconds. This process was repeated until the entirety of the taped off section of pipe was covered by the wipe sample (in sections). Tweezers used in this procedure were decontaminated prior to sample collection, with isopropanol and methanol. The HDPE collection vessel supplied by SGS for wipe transfer was used as the 'blank' wipe sampling test. Following wipe sampling, the wipe was analyzed using LC/MS/MS with TOP assay.

BASELINE RINSE PFAS COMPOSITION



TOF VS. POST-TOP 1633 MASS



APPENDIX C DATA TABLES FOR BASELINE AND FINAL MOBILIZATIONS

Table C1. Total Fluorine Concentration and Mass for Both Mobilizations

		Flushing Volume (L)	Total Fluorine (mg/L)	Inorganic Fluoride (mg/L)	Organic Fluorine (mg/L)	Total Fluorine (mg)	Inorganic Fluoride (mg)	Organic Fluorine (mg)
Baseline Event	Trip Blank	n/a	0.640	< LOD	0.640	n/a	n/a	n/a
	Water Blank	n/a	0.475	0.0467	0.434	n/a	n/a	n/a
	Water Rinse 1	853	< LOQ	0.0682	—	n/a	58.1	n/a
	Water Rinse 2	853	< LOQ	0.0583	—	n/a	49.7	n/a
	Water Rinse 3	853	0.61	0.0582	0.559	522	49.6	477
	Foam Rinse 1	853	23.2	0.180	23.0	19752	153.6	19597
	Foam Rinse 2	853	1.04	0.0791	0.965	886.86	67.5	823
	Foam Rinse 3	853	< LOQ	0.0661	—	n/a	56.4	n/a
Final Event	Trip Blank	n/a	0.029	0.025	0.004	n/a	n/a	n/a
	Water Rinse 1	739	0.03	0.0235	0.004	20.08	17.34	2.73
	Water Rinse 2	739	2.87	0.0332	2.834	2119	24.54	2094
	Water Rinse 3	739	0.07	0.0236	0.046	51.4	17.42	34.02
	Foam Rinse 1	796	0.03	0.0280	0.006	27.06	22.26	4.80
	Foam Rinse 2	796	0.03	0.0250	0.003	22.52	19.92	2.60
	Foam Rinse 3	796	0.03	0.0262	0.003	23.48	20.83	2.65

Table C2. Total PFAS Mass (ng) Pre-TOP Assay for Both Mobilizations (PFCAs)

Mobilization	System Flushed	Flush	Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
Baseline	QA/QC	N/A	WATER-BLANK*	5.77	< 34.1	< 17.1	< 17.1	< 17.1	< 17.1	< 17.1	< 17.1	< 13.9	< 17.1	< 17.1
	Water Only	First	WATER-RINSE-1	28.2	25.0	65.6	29.1	48.8	30.2	14.0	< 17.1	< 13.9	< 17.1	< 17.1
		Second	WATER-RINSE-2	10.0	8.02	27.2	6.05	16.8	5.06	6.80	< 18.1	< 14.7	< 18.1	< 18.1
		Third	WATER-RINSE-3	8.42	5.82	17.7	3.82	11.3	< 78.0	< 78.0	< 78.0	< 14.7	< 78.0	< 78.0
	Foam Concentrate	First	FOAM-RINSE-1	4,350	4,405	15,650	2,865	10,790	< 3,640	< 3,640	< 4,000	< 3,250	< 4,000	657
		Second	FOAM-RINSE-2	100	138	1,480	67.2	300	< 115	37.0	< 115	< 93.4	< 115	< 115
		Third	FOAM-RINSE-3	7.51	9.60	192	7.77	24.4	< 14.2	4.22	< 14.3	< 11.7	< 14.3	< 14.3
Final	QA/QC	N/A	RRAD-MOB2-RB-1*	4.18	0.887	0.861	0.515	0.736	0.505	< 0.398	< 0.398	< 0.318	< 0.398	< 0.398
			RRAD-MOB2-RB-2**	< 1.60	< 0.800	< 0.400	< 0.400	< 0.400	< 0.400	< 0.400	< 0.400	< 0.320	< 0.400	< 0.400
			RRAD-MOB2-RB-3**	< 1.33	< 0.667	< 0.333	< 0.333	< 0.333	< 0.333	< 0.333	< 0.333	< 0.267	< 0.333	< 0.333
	Water Only	First	RRAD-MOB2-W1-1	3.82	0.989	1.24	0.743	1.13	0.444	0.499	< 0.361	< 0.289	< 0.361	< 0.361
			RRAD-MOB2-W2-1	3.72	0.883	0.698	0.474	0.608	0.421	< 0.345	< 0.345	< 0.276	< 0.345	< 0.345
			RRAD-MOB2-W3-1	4.23	0.932	0.816	0.517	0.572	0.358	< 0.319	< 0.319	< 0.255	< 0.319	< 0.319
			RRAD-MOB2-DUP-1	4.52	1.02	1.29	0.972	0.819	0.507	< 0.341	< 0.341	< 0.273	< 0.341	< 0.341
			Average	4.07	0.96	1.01	0.68	0.78	0.43	0.50	n/a	n/a	n/a	n/a
			Standard Deviation	0.37	0.06	0.30	0.23	0.26	0.06	n/a	n/a	n/a	n/a	n/a
		Second	RRAD-MOB2-W1-2	3.7	0.974	1.25	0.778	1.35	0.464	0.36	< 0.323	< 0.258	< 0.323	< 0.323
			RRAD-MOB2-W2-2	3.73	1.02	0.823	0.582	0.806	0.369	< 0.327	< 0.327	< 0.262	< 0.327	< 0.327
			RRAD-MOB2-W3-2	3.71	0.833	0.776	0.653	0.794	< 0.346	< 0.346	< 0.346	< 0.277	< 0.346	< 0.346
			RRAD-MOB2-DUP-2	4.49	0.971	1.69	1.00	1.06	0.531	< 0.321	< 0.321	< 0.257	< 0.321	< 0.321
			Average	3.91	0.95	1.13	0.75	1.00	0.45	0.36	n/a	n/a	n/a	n/a
			Standard Deviation	0.39	0.08	0.43	0.18	0.26	0.08	n/a	n/a	n/a	n/a	n/a
		Third	RRAD-MOB2-W1-3	3.93	1.10	1.61	0.853	1.83	0.49	0.715	< 0.346	< 0.277	< 0.346	< 0.346
			RRAD-MOB2-W2-3	3.49	0.959	0.617	0.653	0.816	0.41	< 0.349	< 0.349	< 0.279	< 0.349	< 0.349
			RRAD-MOB2-W3-3	3.61	0.959	0.839	0.518	0.727	0.36	< 0.323	< 0.323	< 0.259	< 0.323	< 0.323
			RRAD-MOB2-DUP-3	3.68	1.03	1.49	0.826	0.85	0.375	< 0.352	< 0.352	< 0.282	< 0.352	< 0.352
			Average	3.68	1.01	1.14	0.71	1.06	0.41	0.72	n/a	n/a	n/a	n/a
			Standard Deviation	0.19	0.07	0.49	0.16	0.52	0.06	n/a	n/a	n/a	n/a	n/a
	Foam Only	First	RRAD-MOB2-F1-1	3.93	1.08	1.21	0.85	0.813	0.591	< 0.373	< 0.373	< 0.298	< 0.373	< 0.373
			RRAD-MOB2-F2-1	3.67	0.844	0.741	0.552	0.578	0.423	< 0.342	< 0.342	< 0.274	< 0.342	< 0.342
			RRAD-MOB2-F3-1	4.19	1.38	3.34	0.875	1.33	0.395	< 0.332	< 0.332	< 0.265	< 0.332	< 0.332
			Average	3.93	1.10	1.76	0.76	0.91	0.47	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	0.26	0.27	1.39	0.18	0.38	0.11	n/a	n/a	n/a	n/a	n/a
		Second	RRAD-MOB2-F1-2	4.29	0.889	1.26	0.893	0.797	0.408	< 0.366	< 0.366	< 0.292	< 0.366	< 0.366
			RRAD-MOB2-F2-2	3.59	< 0.780	0.771	< 0.390	0.555	0.411	< 0.390	< 0.390	< 0.312	< 0.390	< 0.390
			RRAD-MOB2-F3-2	4.14	1.16	2.49	0.796	0.985	0.415	< 0.322	< 0.322	< 0.257	< 0.322	< 0.322
			Average	4.01	1.02	1.51	0.84	0.78	0.41	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	0.37	0.19	0.89	0.07	0.22	0.00	n/a	n/a	n/a	n/a	n/a
		Third	RRAD-MOB2-F1-3	3.8	1.07	1.45	0.907	0.971	0.548	< 0.397	< 0.397	< 0.318	< 0.397	< 0.397
			RRAD-MOB2-F2-3	3.67	1.08	0.709	0.485	0.685	< 0.412	< 0.412	< 0.412	< 0.412	< 0.412	< 0.412
			RRAD-MOB2-F3-3	4.26	1.40	4.13	0.844	1.38	0.608	< 0.344	< 0.344	< 0.344	< 0.344	< 0.344
			Average	3.91	1.18	2.10	0.75	1.01	0.58	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	0.31	0.19	1.80	0.23	0.35	0.04	n/a	n/a	n/a	n/a	n/a

Table C2 (continued). Total PFAS Mass (ng) pre-TOP Assay for Both Mobilizations (PFSAs, FtSs, PFOSA)

Mobilization	System Flushed	Flush	Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FTS	6:2 FTS	8:2 FTS	PFOSA
Baseline	QA/QC	N/A	WATER-BLANK*	< 17.1	17.10	< 17.1	< 17.1	18.6	< 17.1	< 17.1	< 17.1	< 68.3	< 61.4	< 57.8	< 17.1
	Water Only	First	WATER-RINSE-1	< 17.1	2.37	10.5	< 17.1	47.1	< 17.1	< 17.1	< 17.1	< 68.5	451	28.9	5.21
		Second	WATER-RINSE-2	15.1	13.8	73.5	6.81	236.0	< 18.1	< 18.1	< 18.1	< 72.3	218	20.5	4.69
		Third	WATER-RINSE-3	13.0	10.6	50.6	8.05	245	< 78.0	< 78.0	< 78.0	< 312	124	< 264	14.1
	Foam Concentrate	First	FOAM-RINSE-1	4,054	13,500	80,350	10,970	762,500	< 4,000	< 4,000	< 4,000	< 16,000	145,100	22,000	9,785
		Second	FOAM-RINSE-2	519	815	8,245	647	39,200	< 115	< 115	< 115	< 460	37,450	1,995	54.4
		Third	FOAM-RINSE-3	20.9	45.1	566	50.7	3,510	< 14.3	< 14.3	< 14.3	< 57.4	5,630	221	6.76
Final	QA/QC	N/A	RRAD-MOB2-RB-1*	6.68	< 0.400	< 0.398	< 0.398	0.69	< 0.398	< 0.398	< 0.398	< 1.59	< 1.43	< 1.35	1.86
			RRAD-MOB2-RB-2**	< 0.400	< 0.400	< 0.400	< 0.400	< 0.400	< 0.400	< 0.400	< 0.400	< 1.60	< 1.44	< 1.36	< 0.400
			RRAD-MOB2-RB-3**	< 0.333	< 0.335	< 0.333	< 0.333	< 0.333	< 0.333	< 0.333	< 0.333	< 1.33	< 1.20	< 1.13	< 0.333
	Water Only	First	RRAD-MOB2-W1-1	0.612	< 0.363	0.669	< 0.361	3.04	< 0.361	< 0.361	< 0.361	< 1.45	10.6	< 1.23	1.01
			RRAD-MOB2-W2-1	0.533	< 0.347	< 0.345	< 0.345	1.37	< 0.345	< 0.345	< 0.345	< 1.38	5.19	< 1.17	0.762
			RRAD-MOB2-W3-1	0.641	< 0.321	0.358	< 0.319	2.05	< 0.319	< 0.319	< 0.319	< 1.28	< 1.15	< 1.09	0.96
			RRAD-MOB2-DUP-1	0.577	< 0.343	1.07	< 0.341	5.75	< 0.341	< 0.341	< 0.341	< 1.36	15.3	2.01	0.818
			Average	0.59	n/a	0.70	n/a	3.05	n/a	n/a	n/a	n/a	10.36	2.01	0.89
			Standard Deviation	0.05	n/a	0.36	n/a	1.92	n/a	n/a	n/a	n/a	5.06	n/a	0.12
		Second	RRAD-MOB2-W1-2	0.804	< 0.324	1.14	< 0.323	4.90	< 0.323	< 0.323	< 0.323	< 1.29	13.3	1.43	0.796
			RRAD-MOB2-W2-2	0.558	< 0.329	< 0.327	< 0.327	1.43	< 0.327	< 0.327	< 0.327	< 1.31	3.75	< 1.11	0.675
			RRAD-MOB2-W3-2	0.699	< 0.346	0.361	< 0.346	0.99	< 0.346	< 0.346	< 0.346	< 1.38	< 1.25	< 1.18	0.85
			RRAD-MOB2-DUP-2	0.778	< 0.323	1.03	< 0.321	6.28	< 0.321	< 0.321	< 0.321	< 1.28	18.2	2.73	0.762
			Average	0.71	n/a	0.84	n/a	3.40	n/a	n/a	n/a	n/a	11.75	2.08	0.77
			Standard Deviation	0.11	n/a	0.42	n/a	2.60	n/a	n/a	n/a	n/a	7.35	0.92	0.07
		Third	RRAD-MOB2-W1-3	0.957	< 0.347	1.84	< 0.346	13.1	< 0.346	< 0.346	< 0.346	< 1.38	18.3	1.74	1.1
			RRAD-MOB2-W2-3	0.532	< 0.350	0.368	< 0.349	1.16	< 0.349	< 0.349	< 0.349	< 1.39	4.52	< 1.19	1.03
			RRAD-MOB2-W3-3	0.634	< 0.325	< 0.323	< 0.323	0.916	< 0.323	< 0.323	< 0.323	< 1.29	< 1.17	< 1.10	0.751
			RRAD-MOB2-DUP-3	0.684	< 0.354	< 0.352	< 0.352	5.22	< 0.352	< 0.352	< 0.352	< 1.41	18.3	2.26	1.07
			Average	0.70	n/a	1.10	n/a	5.10	n/a	n/a	n/a	n/a	13.71	2.00	0.99
			Standard Deviation	0.18	n/a	1.04	n/a	5.69	n/a	n/a	n/a	n/a	7.96	0.37	0.16
	Foam Only	First	RRAD-MOB2-F1-1	0.652	< 0.375	0.996	< 0.373	5.00	< 0.373	< 0.373	< 0.373	< 1.49	17.4	2.71	1.09
			RRAD-MOB2-F2-1	0.667	< 0.344	< 0.342	< 0.342	1.60	< 0.342	< 0.342	< 0.342	< 1.37	1.33	< 1.16	0.998
			RRAD-MOB2-F3-1	1.00	0.665	3.69	0.494	27.9	< 0.332	< 0.332	< 0.332	< 1.33	25.8	3.52	0.648
			Average	0.77	0.67	2.34	0.49	11.50	n/a	n/a	n/a	n/a	14.84	3.12	0.91
			Standard Deviation	0.20	n/a	1.90	n/a	14.30	n/a	n/a	n/a	n/a	12.43	0.57	0.23
		Second	RRAD-MOB2-F1-2	0.635	< 0.367	0.934	< 0.366	4.97	< 0.366	< 0.366	< 0.366	< 1.46	16.1	1.99	0.856
			RRAD-MOB2-F2-2	0.49	< 0.392	< 0.390	< 0.390	1.55	< 0.390	< 0.390	< 0.390	< 1.56	< 1.41	< 1.33	1.12
			RRAD-MOB2-F3-2	0.794	0.444	2.44	0.36	20.5	< 0.322	< 0.322	< 0.322	< 1.29	19.2	2.21	0.675
			Average	0.64	0.44	1.69	0.36	9.01	n/a	n/a	n/a	n/a	17.65	2.10	0.88
			Standard Deviation	0.15	n/a	1.06	n/a	10.10	n/a	n/a	n/a	n/a	2.19	0.16	0.22
		Third	RRAD-MOB2-F1-3	0.741	< 0.399	0.897	< 0.397	5.30	< 0.397	< 0.397	< 0.397	< 1.59	17.4	2.58	0.909
			RRAD-MOB2-F2-3	0.597	< 0.414	< 0.412	< 0.412	1.40	< 0.412	< 0.412	< 0.412	< 1.65	< 1.49	< 1.40	2.06
			RRAD-MOB2-F3-3	1.15	0.693	3.77	0.446	30.2	< 0.344	< 0.344	< 0.344	< 1.38	33.2	3.36	0.753
			Average	0.83	0.69	2.33	0.45	12.30	n/a	n/a	n/a	n/a	25.30	2.97	1.24
			Standard Deviation	0.29	n/a	2.03	n/a	15.62	n/a	n/a	n/a	n/a	11.17	0.55	0.71

Table C3. Total PFAS mass (ng) post-TOP assay for both mobilizations (PFCAs)

Mobilization	System Flushed	Flush	Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
Baseline	QA/QC	N/A	WATER-BLANK*	1,430	3,050	1,400	282	26.2	15.0	11.8	< 6.61	< 5.29	< 6.61	< 6.61
	Water Only	First	WATER-RINSE-1	585	1,143	599	142	64.6	36.4	20.5	8.46	< 5.22	< 6.53	< 6.53
		Second	WATER-RINSE-2	3,410	6,905	3,105	688	70.3	34.2	26.5	13.2	< 5.15	< 6.44	< 6.44
		Third	WATER-RINSE-3	2,060	4,330	2,220	373	31.6	17.7	13.8	7.56	5.44	< 6.60	< 6.60
	Foam Only	First	FOAM-RINSE-1	4,595,000	9,780,000	5,565,000	1,097,000	17,400	120,000	89,600	44,500	29,300	21,250	16,850
		Second	FOAM-RINSE-2	120,500	255,500	130,000	32,650	4,565	1,430	918	751	920	1,083	1,420
		Third	FOAM-RINSE-3	13,050	27,050	13,550	3,400	535	225	191	149.0	207	210	287
Final	QA/QC	N/A	RRAD-MOB2-RB-1*	15.6	< 6.12	< 3.06	< 3.06	< 3.06	< 3.06	< 3.06	< 3.06	< 2.45	< 3.06	< 3.06
			RRAD-MOB2-RB-2**	< 13.3	< 6.67	< 3.33	< 3.33	< 3.33	< 3.33	< 3.33	< 3.33	< 2.67	< 3.33	< 3.33
			RRAD-MOB2-RB-2**	< 16.0	< 8.00	< 4.00	< 4.00	6.17	< 4.00	< 4.00	< 4.00	< 3.20	< 4.00	< 4.00
	Water Only	First	RRAD-MOB2-W1-1	19.2	7.24	5.71	< 2.96	3.61	< 2.96	< 2.96	< 2.96	< 2.36	< 2.96	< 2.96
			RRAD-MOB2-W2-1	< 12.1	< 6.07	4.31	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 2.43	< 3.03	< 3.03
			RRAD-MOB2-W3-1	< 11.9	< 5.97	< 2.99	< 2.99	< 2.99	< 2.99	< 2.99	< 2.99	< 2.39	< 2.99	< 2.99
			RRAD-MOB2-DUP-1	13.1	10.6	8.95	< 2.99	< 2.99	< 2.99	< 2.99	< 2.99	< 2.39	< 2.99	< 2.99
			Average	16.15	8.92	6.32	n/a	3.61	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	4.31	2.38	2.38	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Second	RRAD-MOB2-W1-2	15.0	11.5	9.09	< 2.98	3.78	< 2.98	< 2.98	< 2.98	< 2.38	< 2.98	< 2.98
			RRAD-MOB2-W2-2	18.0	< 6.12	3.36	< 3.06	< 3.06	< 3.06	< 3.06	< 3.06	< 2.45	< 3.06	< 3.06
			RRAD-MOB2-W3-2	< 11.9	< 5.94	< 2.97	< 2.97	< 2.97	< 2.97	< 2.97	< 2.97	< 2.38	< 2.97	< 2.97
			RRAD-MOB2-DUP-2	< 11.7	8.78	8.65	< 2.93	< 2.93	< 2.93	< 2.93	< 2.93	< 2.35	< 2.93	< 2.93
			Average	16.50	10.14	7.03	n/a	3.78	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	2.12	1.92	3.19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Third	RRAD-MOB2-W1-3	13.3	13.1	12.7	4.57	5.58	< 3.08	3.13	< 3.08	< 2.47	< 3.08	< 3.08
			RRAD-MOB2-W2-3	< 12.5	< 6.24	4.57	< 3.12	< 3.12	< 3.12	< 3.12	< 3.12	< 2.50	< 3.12	< 3.12
			RRAD-MOB2-W3-3	< 11.8	< 5.91	< 2.96	< 2.96	< 2.96	< 2.96	< 2.96	< 2.96	< 2.36	< 2.96	< 2.96
			RRAD-MOB2-DUP-3	13.0	10.9	7.72	< 2.83	< 2.83	< 2.83	< 2.83	< 2.83	< 2.26	< 2.83	< 2.83
			Average	13.15	12.00	8.33	4.57	5.58	n/a	3.13	n/a	n/a	n/a	n/a
			Standard Deviation	0.21	1.56	4.10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Foam Only	First	RRAD-MOB2-F1-1	< 11.8	8.90	6.90	< 2.95	< 2.95	< 2.95	< 2.95	< 2.95	< 2.95	< 2.95	< 2.95
			RRAD-MOB2-F2-1	< 12.1	< 6.07	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 2.43	< 3.03	< 3.03
			RRAD-MOB2-F3-1	36.6	45.2	30.7	7.89	5.52	< 3.04	< 3.04	< 3.04	< 2.43	< 3.04	< 3.04
			Average	36.60	27.05	18.80	7.89	5.52	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	n/a	25.67	16.83	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Second	RRAD-MOB2-F1-2	< 12.3	10.1	7.50	< 3.08	< 3.08	< 3.08	< 3.08	< 3.08	< 2.47	< 3.08	< 3.08
			RRAD-MOB2-F2-2	< 12.1	< 6.07	< 3.04	< 3.04	< 3.04	< 3.04	< 3.04	< 3.04	< 2.43	< 3.04	< 3.04
			RRAD-MOB2-F3-2	44.9	39.3	29.9	5.44	4.02	< 3.05	< 3.05	< 3.05	< 2.44	< 3.05	< 3.05
			Average	44.90	24.70	18.70	5.44	4.02	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	n/a	20.65	15.84	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Third	RRAD-MOB2-F1-3	17.2	8.87	7.83	2.93	< 2.93	< 2.93	< 2.93	< 2.93	< 2.35	< 2.93	< 2.93
			RRAD-MOB2-F2-3	< 12.4	< 6.19	< 3.10	< 3.10	< 3.10	< 3.10	< 3.10	< 3.10	< 2.48	< 3.10	< 3.10
			RRAD-MOB2-F3-3	38.1	41.5	25.5	5.48	4.16	< 2.97	< 2.97	< 2.97	< 2.38	< 2.97	< 2.97
			Average	27.65	25.19	16.67	4.21	4.16	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	14.78	23.07	12.49	1.80	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table C3 (continued). Total PFAS mass (ng) post-TOP Assay for Both Mobilizations (PFSAs, FtSs, PFOSA)

Mobilization	System Flushed	Flush	Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FTS	6:2 FTS	8:2 FTS	PFOSA
Baseline	QA/QC	N/A	WATER-BLANK*	**9.24**	**7.28**	**29.5**	< 6.61	**127**	< 6.61	< 6.61	< 6.61	< 26.5	**51.1**	< 22.5	< 6.61
	Water Only	First	WATER-RINSE-1	**9.30**	**8.34**	**17.0**	< 6.53	**81**	< 6.53	< 6.53	< 6.53	< 26.1	**158**	< 22.2	< 6.53
		Second	WATER-RINSE-2	**13.0**	**10.50**	**60.7**	**9.46**	**429**	< 6.44	< 6.44	< 6.44	< 25.7	**45.3**	< 21.9	< 6.44
		Third	WATER-RINSE-3	**13.6**	**11.5**	**44.4**	< 6.60	**70.3**	< 6.60	< 6.60	< 6.60	< 26.4	< 23.8	< 22.4	< 6.60
	Foam Only	First	FOAM-RINSE-1	**12,760**	**13,820**	**75,500**	**9,725**	**834,000**	< 5,410	< 5,410	< 5,410	< 21,600	**78,700**	< 18,400	< 5,410
		Second	FOAM-RINSE-2	**530**	**781**	**7,795**	**578**	**37,850**	< 194	< 194	< 194	< 777	**2,925**	< 661	< 194
		Third	FOAM-RINSE-3	**19.6**	**42.8**	**536**	**56.2**	**4,745**	< 9.83	< 9.83	< 9.83	< 39.3	**234**	< 33.4	< 9.83
Final	QA/QC	N/A	RRAD-MOB2-RB-1*	< 3.06	< 3.08	< 3.06	< 3.06	< 3.06	< 3.06	< 3.06	< 3.06	< 12.2	< 11.0	< 10.4	< 3.06
			RRAD-MOB2-RB-2**	< 3.33	< 3.35	< 3.33	< 3.33	< 3.33	< 3.33	< 3.33	< 3.33	< 13.3	< 12.0	< 11.3	< 3.33
			RRAD-MOB2-RB-2**	< 4.00	< 4.02	< 4.00	< 4.00	< 4.00	< 4.00	< 4.00	< 4.00	< 16.0	< 14.4	< 13.6	< 4.00
	Water Only	First	RRAD-MOB2-W1-1	< 2.96	< 2.97	< 2.96	< 2.96	**3.09**	< 2.96	< 2.96	< 2.96	< 11.8	< 10.7	< 10.1	< 2.96
			RRAD-MOB2-W2-1	< 3.03	< 3.05	< 3.03	< 3.03	**5.51**	< 3.03	< 3.03	< 3.03	< 12.1	< 10.9	< 10.3	< 3.03
			RRAD-MOB2-W3-1	< 2.99	< 3.00	< 2.99	< 2.99	< 2.99	< 2.99	< 2.99	< 2.99	< 11.9	< 10.8	< 10.2	< 2.99
			RRAD-MOB2-DUP-1	< 2.99	< 3.00	< 2.99	< 2.99	**5.32**	< 2.99	< 2.99	< 2.99	< 11.9	< 10.8	< 10.2	< 2.99
			Average	n/a	n/a	n/a	n/a	**4.64**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	n/a	n/a	n/a	n/a	**1.35**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Second	RRAD-MOB2-W1-2	< 2.98	< 3.00	< 2.98	< 2.98	**7.33**	< 2.98	< 2.98	< 2.98	< 11.9	< 10.7	< 10.1	< 2.98
			RRAD-MOB2-W2-2	< 3.06	< 3.08	< 3.06	< 3.06	< 3.06	< 3.06	< 3.06	< 3.06	< 12.2	< 11.0	< 10.4	< 3.06
			RRAD-MOB2-W3-2	< 2.97	< 2.98	< 2.97	< 2.97	< 2.97	< 2.97	< 2.97	< 2.97	< 11.9	< 10.7	< 10.1	< 2.97
			RRAD-MOB2-DUP-2	< 2.93	< 2.95	< 2.93	< 2.93	**4.90**	< 2.93	< 2.93	< 2.93	< 11.7	< 10.6	< 9.97	< 2.93
			Average	n/a	n/a	n/a	n/a	**6.12**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	n/a	n/a	n/a	n/a	**1.72**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Third	RRAD-MOB2-W1-3	< 3.08	< 3.10	< 3.08	< 3.08	**28.5**	< 3.08	< 3.08	< 3.08	< 12.3	< 11.1	< 10.5	< 3.08
			RRAD-MOB2-W2-3	< 3.12	< 3.14	< 3.12	< 3.12	< 3.12	< 3.12	< 3.12	< 3.12	< 12.5	< 11.3	< 10.6	< 3.12
			RRAD-MOB2-W3-3	< 2.96	< 2.97	< 2.96	< 2.96	< 2.96	< 2.96	< 2.96	< 2.96	< 11.8	< 10.7	< 10.1	< 2.96
			RRAD-MOB2-DUP-3	< 2.83	< 2.84	< 2.83	< 2.83	**4.71**	< 2.83	< 2.83	< 2.83	< 11.3	< 10.2	< 9.61	< 2.83
			Average	n/a	n/a	n/a	n/a	**16.61**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	n/a	n/a	n/a	n/a	**16.82**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Foam Only	First	RRAD-MOB2-F1-1	< 2.95	< 2.97	< 2.95	< 2.95	**4.47**	< 2.95	< 2.95	< 2.95	< 11.8	< 10.6	< 10.0	< 2.95
			RRAD-MOB2-F2-1	< 3.03	< 3.05	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 12.1	< 10.9	< 10.3	< 3.03
			RRAD-MOB2-F3-1	< 3.04	< 3.05	< 3.04	< 3.04	**27.8**	< 3.04	< 3.04	< 3.04	< 12.2	< 11.0	< 10.3	< 3.04
			Average	n/a	n/a	n/a	n/a	**16.14**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	n/a	n/a	n/a	n/a	**16.50**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Second	RRAD-MOB2-F1-2	< 3.08	< 3.10	< 3.08	< 3.08	**5.85**	< 3.08	< 3.08	< 3.08	< 12.3	< 11.1	< 10.5	< 3.08
			RRAD-MOB2-F2-2	< 3.04	< 3.05	< 3.04	< 3.04	< 3.04	< 3.04	< 3.04	< 3.04	< 12.1	< 10.9	< 10.3	< 3.04
			RRAD-MOB2-F3-2	< 3.05	< 3.07	**3.41**	< 3.05	**22.5**	< 3.05	< 3.05	< 3.05	< 12.2	< 11.0	< 10.4	< 3.05
			Average	n/a	n/a	**3.41**	n/a	**14.18**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	n/a	n/a	n/a	n/a	**11.77**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Third	RRAD-MOB2-F1-3	< 2.93	< 2.95	< 2.93	< 2.93	**4.42**	< 2.93	< 2.93	< 2.93	< 11.7	< 10.6	< 9.97	< 2.93
			RRAD-MOB2-F2-3	< 3.10	< 3.11	< 3.10	< 3.10	< 3.10	< 3.10	< 3.10	< 3.10	< 12.4	< 11.2	< 10.5	< 3.10
			RRAD-MOB2-F3-3	< 2.97	< 2.99	< 2.97	< 2.97	**21.6**	< 2.97	< 2.97	< 2.97	< 11.9	< 10.7	< 10.1	< 2.97
			Average	n/a	n/a	n/a	n/a	**13.01**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
			Standard Deviation	n/a	n/a	n/a	n/a	**12.15**	n/a	n/a	n/a	n/a	n/a	n/a	n/a

APPENDIX D DATA TABLES FOR COMPONENT CHARACTERIZATION

Table D1. Individual Part IDs, Descriptions, and Analyses.

Part ID	Piece ID	Material	Geometry	System Location	Baseline Water Flush	Method 1633	TOF	XPS	RZA	Wetted Surface Area (cm^2)
1	A	SS	Straight	Mixed		✓	✓	✓	✓	5450
1	B	SS	Straight	Mixed		✓		✓	✓	1320
1	C	SS	Straight	Mixed		✓		✓	✓	992
1	D	SS	Elbow	Mixed		✓			✓	1480
1	E	SS	Elbow	Mixed		✓			✓	1290
2	A	SS	Straight	Mixed		✓		✓	✓	2770
2	B	SS	Elbow	Mixed		✓			✓	3450
3	A	Brass	Valve	Water		✓		✓	✓	961
4	A	Brass	Valve	Mixed		✓	✓	✓	✓	254
5	A	Brass	Valve	Foam	✓	✓		✓	✓	339
5	B	Brass	Valve	Foam	✓				✓	
6	A	Brass	Valve	Foam	✓	✓	✓	✓	✓	331
7	A	SS	Straight	Mixed		✓			✓	760
8	A	Hose	Straight	Mixed		✓				307
9	A	Brass	Unique	Mixed		✓		✓	✓	112
9	B	Brass	Unique	Mixed					✓	138
9	C	Brass	Unique	Mixed					✓	161
10	A	SS	Unique	Foam		✓			✓	1040
10	B	SS	Unique	Foam		✓			✓	713
11	A	SS	Unique	Foam		✓			✓	653
12	A	SS	Straight	Foam		✓			✓	1330
12	B	SS	Elbow	Foam		✓			✓	979
13	A	SS	Straight	Foam		✓			✓	1540
13	B	SS	Straight	Foam		✓			✓	1540
14	A	Aluminum	Unique	Water	✓	✓			✓	1120
14	D	Aluminum	Straight	Water	✓	✓			✓	1240
14	B	Brass	Straight	Water	✓	✓			✓	901
14	C	SS	Unique	Water	✓	✓			✓	469
15	C	Brass	Straight	Water	✓	✓			✓	938
15	D	Plastic	Unique	Water	✓	✓	✓	✓	✓	134
15	A	SS	Unique	Water	✓	✓			✓	1510
15	B	SS	Unique	Water	✓	✓			✓	1140
17	A	Brass	Valve	Water	✓	✓			✓	1510
17	B	Brass	Valve	Water	✓	✓		✓	✓	1140
18	A	SS	Straight	Water	✓	✓			✓	1510
18	B	SS	Straight	Water	✓	✓			✓	780
19	A	Brass	Valve	Mixed	✓	✓			✓	257
20	A	SS	Elbow	Foam	✓	✓	✓		✓	460
21	A	SS	Straight	Foam		✓		✓	✓	1880

Part ID	Piece ID	Material	Geometry	System Location	Baseline Water Flush	Method 1633	TOF	XPS	RZA	Wetted Surface Area (cm^2)
22	A	SS	Unique	Foam	✓	✓			✓	1370
23	A	SS	Straight	Foam	✓	✓			✓	2170
23	B	SS	Straight	Foam	✓	✓			✓	845
24	A	Brass	Unique	Foam		✓			✓	1650
24	B	Brass	Unique	Foam		✓			✓	1600
25	A	Brass	Unique	Foam		✓			✓	1350
26	A	Mixed	Unique	Foam		✓	✓		✓	1520
27	A	SS	Straight	Foam	✓	✓	✓	✓	✓	2320
28	A	SS	Straight	Foam	✓	✓	✓	✓	✓	2270
28	B	SS	Elbow	Foam	✓	✓		✓ (ext.)	✓	667
29	A	Brass	Valve	Foam	✓	✓	✓	✓	✓	747
31	B	Plastic	Straight	Water	✓	✓			✓	1160
31	A	SS	Unique	Water	✓	✓			✓	443
32	A	SS	Straight	Water	✓	✓	✓	✓	✓	1590
33	A	SS	Straight	Water	✓	✓		✓	✓	969
33	B	SS	Elbow	Water	✓	✓	✓		✓	4510
34	A	SS	Straight	Water	✓	✓	✓	✓	✓	2390
34	B	SS	Elbow	Water	✓	✓			✓	5030
35	A	Aluminum	Unique	Water	✓	✓		✓	✓	1480
35	B	Aluminum	Straight	Water	✓	✓		✓	✓	884
36	B	Brass	Straight	Water	✓				✓	3730
36	C	Brass	Straight	Water	✓	✓			✓	975
36	D	SS	Unique	Water	✓	✓			✓	1510
36	A	SS	Straight	Water	✓	✓			✓	3730
37	B	Brass	Cap	Water	✓	✓		✓	✓	187
37	C	Plastic	Unique	Water	✓	✓	✓	✓	✓	134
37	A	SS	Straight	Water	✓	✓			✓	1610
38	A	Brass	Valve	Water	✓	✓	✓		✓	731
39	A	Brass	Straight	Foam	✓	✓	✓	✓ (ext.)	✓	505
39	B	Mixed	Unique	Foam	✓	✓		✓	✓	605
40	A	Brass	Straight	Water	✓	✓	✓	✓	✓	505
40	B	Mixed	Unique	Water	✓	✓			✓	605
41	A	SS	Straight	Water	✓	✓			✓	754
42	A	SS	Straight	Water	✓	✓	✓	✓	✓	1420
43	A	SS	Elbow	Foam	✓	✓	✓	✓	✓	1220
44	A	Plastic	Straight	Foam		✓		✓		4710
45	A	SS	Unique	Foam	✓	✓			✓	2140
46	A	SS	Straight	Foam	✓				✓	
47	A	Brass	Unique	Mixed					✓	
47	B	Brass	Unique	Mixed					✓	
47	C	Brass	Unique	Mixed					✓	
47	D	Brass	Unique	Mixed		✓			✓	5510

Part ID	Piece ID	Material	Geometry	System Location	Baseline Water Flush	Method 1633	TOF	XPS	RZA	Wetted Surface Area (cm^2)
47	E	Brass	Unique	Mixed		✓			✓	2430
48	A	Hose	Straight	Mixed		✓	✓	✓ (w and w/o ext.)		817
49	A	Hose	Straight	Mixed		✓				638
50	A	Hose	Straight	Mixed		✓	✓	✓		648
51	A	Hose	Straight	Mixed		✓		✓		1150
53	A	Hose	Straight	Water	✓	✓	✓	✓		1140
54	E	Brass	Unique	Mixed		✓	✓		✓	N/A
54	B	Hose	Straight	Mixed		✓	✓		✓	1170
54	C	Hose	Straight	Mixed		✓			✓	1380
54	D	Hose	Straight	Mixed		✓			✓	1530
54	A	Plastic	Straight	Mixed		✓	✓	✓	✓	1320
56	A	SS	Straight	Mixed		✓	✓	✓	✓	1670
56	B	SS	Straight	Mixed		✓			✓	696
57	A	SS	Straight	Mixed		✓		✓	✓	3660
57	B	SS	Elbow	Mixed		✓			✓	2130
57	C	SS	Elbow	Mixed		✓			✓	2420
58	A	SS	Straight	Mixed		✓		✓	✓	1670
59	A	SS	Straight	Mixed		✓	✓		✓	4470
60	A	SS	Unique	Mixed		✓			✓	325
61	A	Plastic	Straight	Foam	✓	✓	✓	✓		N/A
61	B	Plastic	Elbow	Foam	✓	✓		✓		N/A
62	A	SS	Straight	Mixed		✓	✓	✓	✓	6710
63	A	SS	Straight	Mixed		✓			✓	9120
64	A	Carbon Steel*	Unique	Mixed		✓				905000
73	B	Brass	Unique	Mixed		✓		✓	✓	1390
73	A	Hose	Straight	Mixed		✓			✓	574
74	B	Brass	Elbow	Mixed		✓				949
74	A	Mixed - Carbon Steel* with Brass Fittings	Unique	Mixed		✓			✓	3140
75	B	Brass	Unique	Mixed				✓	✓	1390
75	A	Hose	Straight	Mixed					✓	574
76	A	Mixed - Carbon Steel* with Brass Fittings	Unique	Mixed		✓		✓	✓	2970
77	A	SS	Unique	Mixed		✓			✓	6990
78	A	SS	Straight	Dry Chemical		✓		✓	✓	2030
78	B	SS	Elbow	Mixed		✓			✓	834
79	A	Brass	Valve	Mixed		✓	✓		✓	294
80	A	Hose	Straight	Mixed		✓		✓	✓	501
81	A	Brass	Valve	Dry Chemical		✓	✓		✓	259
81	B	Hose	Straight	Dry Chemical		✓	✓	✓	✓	1370
81	C	SS	Elbow	Mixed		✓			✓	480

Part ID	Piece ID	Material	Geometry	System Location	Baseline Water Flush	Method 1633	TOF	XPS	RZA	Wetted Surface Area (cm^2)
82	A	SS	Straight	Mixed		✓	✓		✓	6700
Foam Baffle 1	Baffle	Plastic	Tank	Foam	✓	✓	✓	✓		50500
Foam Baffle 2	Baffle	Plastic	Tank	Foam	✓	✓	✓	✓		50500
Foam Baffle 3	Baffle	Plastic	Tank	Foam	✓	✓				50500
Foam Baffle 4	Baffle	Plastic	Tank	Foam	✓	✓				50500
Foam Baffle 5	Baffle	Plastic	Tank	Foam	✓	✓				50500
Foam Baffle 6	Baffle	Plastic	Tank	Foam	✓	✓				50500
Foam Baffle 7	Baffle	Plastic	Tank	Foam	✓	✓				50500
Foam Baffle 8	Baffle	Plastic	Tank	Foam	✓	✓				50500
Foam Baffle 9	Baffle	Plastic	Tank	Foam	✓	✓				50500
Water Baffle 1	Baffle	Plastic	Tank	Water	✓	✓				905000
Water Baffle 2	Baffle	Plastic	Tank	Water	✓	✓				905000
Water Baffle 3	Baffle	Plastic	Tank	Water	✓	✓	✓	✓		905000
Water Baffle 4	Baffle	Plastic	Tank	Water	✓	✓	✓	✓		905000
Water Baffle 5	Baffle	Plastic	Tank	Water	✓	✓				905000
Water Baffle 6	Baffle	Plastic	Tank	Water	✓	✓				905000
Water Baffle 7	Baffle	Plastic	Tank	Water	✓	✓				905000
Water Baffle 8	Baffle	Plastic	Tank	Water	✓	✓				905000
Water Baffle 9	Baffle	Plastic	Tank	Water	✓	✓				905000

Table D2. XPS Results for Individual Components.

Sample ID	Data Units	Al	C	Ca	Cl	Cr	Cu	F	Fe	Mg	N	Na	O	P	Pb	S	Si	Sn	Zn
01-A	%	<0.01	41.2	<0.5	1.2	<0.01	6.5	1.3	1.3	<0.1	1.3	<0.01	40.8	3.7	<0.01	<0.6	<0.5	<0.01	<0.9
01-B	%	1.9	46.2	<0.5	1.1	<0.01	4.7	1.5	1.7	<0.01	1.9	<0.5	34.1	4.5	<0.2	<0.01	<0.01	<0.01	1
01-C	%	<0.9	70.6	<0.4	<0.3	<0.01	1.5	2.7	<0.6	<0.01	4.3	<0.01	17.4	<0.5	<0.01	<0.5	<0.01	<0.01	<0.3
02-A	%	1.1	39.2	<0.4	<0.2	3.3	3.4	<0.6	2.6	<0.01	1.9	<0.01	42.2	2.5	<0.1	<0.2	<0.8	<0.01	1.7
03-A	%	<0.01	41	<0.5	<0.2	<0.01	7	2.3	<0.01	<0.01	1.2	<0.01	40.2	1.7	<0.5	<0.9	<0.01	<0.01	4.4
04-A	%	<0.01	49.3	<0.1	<0.01	<0.01	8	5	<0.01	<0.01	4.4	<0.01	31.5	<0.01	<0.1	<0.6	<0.01	<0.01	1.1
05-A	%	<0.01	65.5	<0.01	<0.01	<0.01	4.7	5.1	<0.01	<0.01	14.2	<0.01	10.1	<0.01	<0.01	<0.2	<0.01	<0.01	<0.1
06-A	%	<0.01	58.6	<0.01	<0.01	<0.01	2.4	12	<0.8	<0.01	6.6	<0.01	17.9	<0.01	<0.2	1.1	<0.1	<0.01	<0.2
09-A	%	<0.01	54.1	<0.01	<0.01	<0.01	7.4	6.2	<0.01	<0.01	2.2	<0.01	27.5	1.3	<0.1	<0.4	<0.01	<0.3	<0.5
09-B	%	<0.01	40.2	<0.1	<0.01	<0.01	10.1	6.8	<0.01	<0.01	2.4	<0.01	34.3	1.3	<0.3	<0.5	1.7	<0.9	1.3
09-C	%	<0.01	39.5	<0.01	<0.01	<0.01	9	3.4	<0.01	<0.01	2.9	<0.01	40.2	2.2	<0.3	<0.01	<0.01	<0.1	2.4
15-D	%	<0.01	53.7	<0.8	<0.4	<0.01	<0.3	<0.7	<0.9	<0.01	<0.7	<0.4	39.7	1.1	<0.5	<0.1	<0.01	<0.01	<0.6
17-B	%	<0.01	71.4	<0.5	<0.2	<0.01	<0.3	<0.5	<0.01	<0.01	1.6	<0.1	23.9	<0.3	<0.01	<0.2	<0.6	<0.01	<0.4
21-A	%	<0.01	47.9	<0.4	<0.01	1.2	<0.6	23.1	<0.7	<0.01	3.5	<0.5	19.9	<0.01	<0.1	<0.6	<0.01	<0.01	<0.01
27-A	%	<0.3	55.9	2	<0.2	1.7	<0.1	11.1	1	<0.4	2.1	<0.3	23.2	<0.2	<0.1	<0.9	<0.5	<0.01	<0.1
28-A	%	<0.01	50.3	1.5	<0.1	<0.8	<0.2	21	<0.01	<0.3	2.1	<0.2	21.5	<0.2	<0.01	<0.9	<0.8	<0.1	<0.01
28-B-Extracted	%	<0.01	65.3	<0.6	<0.01	1.4	<0.01	<0.01	1.8	<0.01	2.5	<0.01	26.7	<0.01	<0.01	<0.01	1.3	<0.01	<0.2
29-A	%	<0.01	67.1	<0.4	<0.01	<0.01	3.7	1.8	<0.01	<0.1	13.9	<0.01	12.6	<0.01	<0.1	<0.01	<0.01	<0.2	<0.2
32-A	%	<0.6	57.8	<0.7	<0.1	1	<0.2	2.4	1	<0.1	1.1	<0.01	27.6	<0.4	<0.01	<0.2	4.9	<0.01	1.8
33-A	%	1.7	39.6	<0.4	<0.01	<0.01	6.3	1.4	1.4	<0.01	2.3	<0.01	40.9	3.7	<0.2	<0.1	<0.01	<0.01	1.9
34-A	%	1.2	43.1	<0.4	<0.01	<0.01	<0.7	1	1.2	<0.1	1.5	<0.01	39.3	<0.4	<0.01	<0.01	6.3	<0.01	5
35-A	%	2.6	32.9	<0.2	<0.01	<0.01	<0.2	<0.01	<0.01	<0.01	1.2	<0.01	44.6	3.2	<0.01	<0.01	3.3	<0.01	12
35-B	%	4	43.4	<0.3	<0.01	<0.01	<0.2	<0.01	<0.01	<0.01	<0.9	<0.01	37.6	2.4	<0.01	<0.3	2.9	<0.01	8
37-B	%	<0.01	50.7	<0.01	<0.01	<0.01	4.8	<0.01	<0.8	<0.01	2.4	<0.01	36.6	1.6	<0.5	<0.01	<0.7	<0.01	1.9
37-C	%	<0.01	59.7	<0.5	<0.2	<0.01	1.4	<0.01	<0.01	<0.01	1.8	<0.4	34	<0.9	<0.3	<0.01	<0.01	<0.01	<0.8
39-A-Extracted	%	<0.01	46.7	<0.5	<0.01	<0.01	6.1	9.7	<0.01	<0.2	2.4	<0.01	29.8	<0.01	<0.01	2.1	<0.01	<0.01	1.5
39-B-Exterior	%	<0.8	56.9	<0.6	<0.01	<0.01	<0.2	15.2	<0.01	<0.2	4	<0.01	17.9	<0.01	<0.01	3.5	<0.5	<0.01	<0.2
40-A	%	<0.01	54.6	<0.5	<0.1	<0.01	3	2	<0.01	<0.01	1	<0.2	30.5	<0.6	<0.01	<0.2	1.4	<0.01	6
42-A	%	<0.01	54.1	<0.5	<0.01	<0.01	3.9	<0.8	1.3	<0.01	1.9	<0.01	33.4	1.2	<0.3	<0.01	1.5	<0.01	1.1
43-A	%	<0.01	59.9	1.7	<0.3	<0.5	<0.1	14	<0.01	<0.2	2.2	<0.9	18.5	<0.01	<0.01	<0.7	<0.9	<0.01	<0.1
44-A	%	<0.3	47.2	<0.1	<0.3	<0.01	<0.01	29.1	<0.01	<0.2	3	<0.8	16.4	<0.01	<0.01	2.3	<0.2	<0.01	<0.01
48-A	%	<0.01	53.2	<0.2	<0.2	<0.01	<0.1	21.6	<0.01	<0.1	2.8	<0.01	20.2	<0.2	<0.01		<0.8	<0.01	<0.1

Sample ID	Data Units	Al	C	Ca	Cl	Cr	Cu	F	Fe	Mg	N	Na	O	P	Pb	S	Si	Sn	Zn
48-A-Extracted	%	<0.01	62.8	<0.01	<0.4	<0.01	<0.01	1	<0.01	<0.01	1.9	<0.01	24.8	<0.01	<0.01	<0.1	8.7	<0.01	<0.3
50-A	%	<0.01	67	<0.3	<0.1	<0.01	<0.3	4.3	1.2	<0.01	3.7	<0.01	21.3	<0.6	<0.01	<0.5	<0.6	<0.01	<0.2
51-A	%	<0.01	51.7	<0.01	<0.5	<0.01	<0.01	13.5	<0.7	<0.01	1.3	<0.01	21.6	<0.01	<0.01	<0.5	10.1	<0.01	<0.1
53-A	%	1.1	66.9	<0.3	<0.1	<0.01	<0.2	3.4	<0.4	<0.01	5	<0.01	21.4	<0.4	<0.01	<0.4	<0.3	<0.01	<0.2
54-A	%	<0.01	73.3	<0.6	<0.01	<0.01	<0.3	1.9	<0.01	<0.1	3.1	<0.01	18.6	<0.2	<0.01	<0.3	1	<0.01	<0.8
56-A	%	<0.8	55.7	<0.8	<0.01	1.4	2.2	2.3	<0.4	<0.01	1.5	<0.01	29.9	1.1	<0.1	<0.2	1.8	<0.01	1.7
57-A	%	<0.6	45.1	<0.01	<0.01	3.1	3.7	2.1	2.1	<0.01	2.4	<0.01	37.6	2.1	<0.1	<0.01	<0.3	<0.01	<0.8
58-A	%	<0.8	57.2	<0.5	<0.4	<0.5	3.1	2.6	<0.1	<0.1	1.5	<0.01	29.2	<0.9	<0.1	<0.4	1.7	<0.01	<0.9
61-A-Exterior	%	<0.01	71.2	<0.01	<0.2	<0.01	<0.01	11.4	<0.01	<0.2	2.1	<0.5	12.1	<0.01	<0.01	<0.7	1.5	<0.01	<0.1
61-A-Interior	%	<0.7	68.9	<0.01	<0.3	<0.01	<0.01	9.6	<0.01	<0.1	1.6	<0.5	15	<0.01	<0.01	<0.8	2.2	<0.01	<0.2
61-B-Exterior	%	<0.01	64	<0.1	<0.1	<0.01	<0.1	18.4	<0.01	<0.1	2.2	<0.7	11.6	<0.01	<0.01	1.5	<0.7	<0.01	<0.1
61-B-Interior	%	<0.4	49.8	<0.01	<0.01	<0.01	<0.01	25.2	<0.01	<0.2	3.3	<0.7	17.8	<0.01	<0.01	2.3	<0.3	<0.01	<0.01
62-A	%	1.4	37.8	1.2	<0.01	1.9	3.1	1.6	1.1	<0.01	1.7	<0.01	43.5	2.3	<0.01	<0.3	2.3	<0.01	1.7
33-A	%	1.7	39.6	<0.4	<0.01	<0.01	6.3	1.4	1.4	<0.01	2.3	<0.01	40.9	3.7	<0.2	<0.1	<0.01	<0.01	1.9
34-A	%	1.2	43.1	<0.4	<0.01	<0.01	<0.7	1	1.2	<0.1	1.5	<0.01	39.3	<0.4	<0.01	<0.01	6.3	<0.01	5
Water Baffle 1	%	<0.4	78.9	<0.7	<0.4	<0.01	<0.01	<0.01	<0.7	<0.01	<0.3	<0.01	15.5	<0.2	<0.01	<0.1	1.1	<0.01	1.7
Water Baffle 2	%	<0.01	90.9	<0.3	<0.2	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	7.2	<0.01	<0.01	<0.1	<0.5	<0.01	<0.6
Foam Baffle 1	%	<0.01	85.2	1.3	<0.01	<0.01	<0.01	2.2	<0.01	<0.01	<0.6	<0.1	9.4	<0.01	<0.01	<0.2	1	<0.01	<0.01
Foam Baffle 2	%	<0.01	86.4	<0.9	<0.01	<0.01	<0.01	3.6	<0.01	<0.01	<0.6	<0.01	7.5	<0.01	<0.01	<0.3	<0.6	<0.01	<0.01
73-B	%	<0.01	38.1	<0.01	<0.01	<0.01	8.7	<0.5	<0.01	<0.01	2.5	<0.01	43.7	1.8	<0.2	<0.01	<0.01	<0.01	4.6
75-B	%	<0.01	38.2	<0.2	<0.01	<0.01	8.4	<0.01	<0.01	<0.01	2.6	<0.01	43.1	4.3	<0.1	<0.01	<0.6	<0.01	2.5
76-A	%	<0.01	60.9	<0.4	1.2	<0.01	1.4	<0.01	1.1	<0.4	1.3	1.2	<0.9	<0.9	<0.1	<0.01	<0.6	<0.01	<0.7
78-A-Exterior	%	1.6	62	1.4	<0.6	<0.3	<0.01	2.7	<0.9	<0.1	<0.8	<0.4	24.9	<0.01	<0.01	<0.4	3.6	<0.01	<0.2
78-A-Interior	%	<0.8	41.9	<0.6	<0.01	1.2	4.6	2.6	1.9	<0.01	2	<0.01	39.1	2.8	<0.1	<0.01	1.1	<0.01	1.3
80-A	%	3.5	61.9	<0.8	<0.01	<0.01	<0.6	<0.01	<0.01	<0.01	5.1	<0.01	25.2	<0.01	<0.01	<0.01	1.2	<0.01	1.7
81-B	%	<0.01	71.8	<0.01	<0.3	<0.01	<0.01	<0.8	<0.01	<0.01	3.8	<0.01	22	<0.01	<0.01	<0.1	<0.01	<0.01	1.1

Notes:

SS: Stainless steel

%: Percent

Table D3. Total Mass of Fluorine for Each Component

	Total Mass	Total Fluorine	Inorganic Fluoride	Organic Fluorine
01-A	ug	151	ND	151
04-A	ug	513	0.91	510
06-A	ug	1650	11.4	1640
15-D	ug	11.5	1.21	10.3
20-A	ug	63.0	8.25	54.8
26-A	ug	313	17.4	296
27-A	ug	506	11.3	495
28-A	ug	1140	87.4	1060
29-A	ug	3900	5.88	3900
32-A	ug	66.3	ND	66.3
33-B-1	ug	329	16.3	313
33-B-2	ug	959	22.8	935
33-B-3	ug	763	14.3	749
33-B-4	ug	710	26.7	684
33-B-5	ug	422	20.5	401
34-A	ug	30.3	ND	30.3
37-C	ug	0.01	ND	0.01
38-A	ug	39.3	3.86	35.6
39-A	ug	8590	5960	2620
40-A	ug	9250	9100	145
42-A	ug	162	22.6	139
43-A	ug	4210	385	3830
48-A	ug	3820	ND	3920
50-A	ug	162	ND	162
53-A	ug	377	62.6	315
54-A	ug	330	ND	330
54-B-1	ug	350	44.0	306
54-B-2	ug	313	ND	313
54-B-3	ug	376	11.7	364
54-B-4	ug	324	ND	324
54-B-5	ug	407	ND	407
56-A	ug	48.1	39.4	6.42
59-A-1	ug	231	21.5	209
59-A-2	ug	215	21.7	193
59-A-3	ug	255	37.7	217
59-A-4	ug	243	43.9	200
59-A-5	ug	227	27.8	199
62-A-1	ug	270	424	ND
79-A	ug	237	1.12	235
81-A	ug	83.2	0	83.2
81-B	ug	4.78	ND	4.78

	Total Mass	Total Fluorine	Inorganic Fluoride	Organic Fluorine
82-A-1	ug	93.1	50.8	42.3
82-A-2	ug	289	50.6	238
82-A-3	ug	358	91.8	266
82-A-4	ug	92.7	ND	92.7
Blank 1	ug	ND	ND	ND
Blank 7	ug	ND	ND	ND
Blank 9	ug	ND	ND	ND
Foam Baffle 1	ug	6350	ND	6350
Foam Baffle 2	ug	6980	ND	6980
Foam Baffle 3	ug	7290	ND	7290
Foam Baffle 4	ug	5330	ND	5330
Foam Baffle 5	ug	3820	ND	3820
Foam Baffle 6	ug	3950	ND	3950
Foam Baffle 7	ug	5620	ND	5620
Water Baffle 1	ug	52500	ND	52500
Water Baffle 2	ug	43000	ND	43000
Water Baffle 3	ug	274000	ND	274000
Water Baffle 4	ug	157000	ND	157000
Water Baffle 5	ug	89300	ND	89300
Water Baffle 6	ug	88800	ND	88800
Water Baffle 7	ug	75200	ND	75200

Table D4. Mass (ng) of Individual and Summed PFAS pre-TOP Assay for Each Component (PFCAs)

Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
01-A	349	174	2472	1292	871	860	677	871	419	666	1169
01-B	77.9	232	2530	761	1044	504	572	334	436	416	524
01-C	99.8	461	3318	1298	1138	654	531	495	343	344	718
01-D	<152	75.8	1016	502	741	460	427	292	344	367	567
01-D-Wipe	<148	<74.1	<36.9	<36.9	<36.9	<36.9	<36.9	<36.9	<29.6	<36.9	<36.9
01-E	<129	64.4	331	175	278	228	170	217	128	199	524
02-A	Ttt661	1448	10264	19739	3255	4869	1544	1544	692	628	1369
02-B	<274	137	1870	3465	1019	1853	859	1320	642	698	1097
03-A-Wipe	***78.1***	***39.2***	1150	519	3434	1434	1500	504	588	210	765
04-A	<3840	<1920	16704	960	15648	960	12144	3898	8818	4478	7402
05-A-Wipe	267	463	2322	253	377	67.3	179	43.0	101	***6.95***	47.0
06-A	<7520	<3760	31020	1880	22372	<1880	1880	<1880	<1500	<1880	<1880
07-A	<1370	<6830	18122	3413	3413	<3410	3413	<3410	2730	<3410	<3410
08-A	<68100	<34000	17019	<18	<17000	<173	<18	<173	<13600	<173	<173
09-A-Wipe	<11.1	***5.57***	84.4	19.3	126	34.0	41.7	11.6	11.5	***2.78***	***2.78***
09-B-Wipe	***13.9***	46.3	470	70.7	470	136	227	82.3	104	43.5	55.2
09-C-Wipe	<16.2	***8.10***	273	46.5	304	76.5	182	47.1	77.2	33.4	48.8
10-A	<872	436	4842	4853	2317	1854	1614	1685	1467	1407	1292
10-B	<542	271	4235	4844	1880	2224	1038	1264	827	820	799
11-A	<14300	<7170	3586	3586	<3590	<3590	<3590	<3590	<2870	<3590	<3590
12-A	<20300	<10100	<5070	<5070	<5070	<5070	<5070	<5070	<4050	<5070	<5070
12-B	<2390	<120	5965	<5970	5965	<5970	<5970	<5970	<4770	<5970	<5970
13-A	<36300	<18200	9078	<9080	9078	<9080	<9080	<9080	<7260	<9080	<9080
13-B	<35200	<17600	8790	<8790	8790	<8790	<8790	<8790	<7030	<8790	<8790
14-A-Wipe	<87.9	<44	***22.0***	<22	***22.0***	<22	116	***22.0***	***17.6***	***22.0***	***22.0***
14-B-Wipe	<68.9	<34.3	85.8	***17.2***	***17.2***	***17.2***	***17.2***	***17.2***	***13.7***	***17.2***	***17.2***
14-C	<6720	<3360	<1680	<1680	1680	<1680	1680	<1680	5729	1680	1680
14-D-Wipe	<101	<50.3	***25.1***	<25.1	***25.1***	<25.1	***25.1***	<25.1	***20.1***	<25.1	***25.1***
15-A	<1470	733	7888	4031	3436	2103	2071	366	1429	366	366
15-B	<12400	620	4442	1442	4396	1845	3690	1740	1376	310	310
15-C-Wipe	<87.5	<43.9	145	***21.9***	***21.9***	<21.9	***21.9***	<21.9	<17.5	<21.9	<21.9
15-D	***28.0***	57.8	356	80.5	111	28.9	48.4	7.00	24.2	7.00	7.00
17-A-Wipe	<136	<68.2	<34.0	<34	<34.0	<34	<34	<3360	<27.2	<3360	<34
17-B-Wipe	<106	<53.4	408	***26.6***	148	***26.6***	***26.6***	***26.6***	<21.3	<26.6	<26.6
18-A	<334	167	1527	511	708	83.4	384	83.4	334	83.4	83.4
18-B	<133	66.6	716	343	273	143	145	33.3	26.7	33.3	33.3
19-A	<3800	<1900	12065	950	7201	950	950	950	3116	950	950
20-A	<422	211	1539	105	567	105	105	105	84.4	<105	105
21-A	<29300	<14600	7320	<7320	<7320	<7320	<7320	<7320	<5860	<7320	<7320
21-A-Wipe	<145	***72.6***	703	155	322	***36.3***	***36.3***	<36.3	<29.1	<36.3	<36.3
22-A	<19600	<9800	4902	<4900	4902	<4900	<4900	<4900	<3920	<4900	<4900
23-A	<59600	<29800	14902	<14900	14902	<14900	<14900	<14900	<11900	<14900	<14900
23-B	<22400	<11200	5596	<5600	5596	<5600	<5600	<5600	<4480	<5600	<5600
24-A-Wipe	<162	<81.1	376	***40.5***	243	<40.5	***40.5***	<40.5	<32.4	<40.5	<40.5

Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
24-B-Wipe	<344	***172***	940	***86.4***	626	<86.4	***86.4***	<86.4	<69.1	<86.4	<86.4
25-A-Wipe-1	<691	<346	2246	***173***	1479	<18	***173***	<177	<138	<177	<177
25-A-Wipe-2	<724	***363***	5508	1150	3245	***181***	848	<181	***145***	<181	<181
25-A-Wipe-3	<707	***353***	3737	842	2246	***177***	***177***	<18	***141***	<18	<18
25-A-Wipe-4	<132	***66.4***	848	229	637	***33.2***	242	***33.2***	***26.5***	<33.2	***33.2***
25-A-Wipe-5	<288	***144***	1420	340	1031	***71.8***	376	<71.8	***57.8***	<71.8	***71.8***
26-A	<25100	<12500	<6270	<6270	<6270	<6270	<6270	<6270	<5010	<6270	<6270
27-A	***230***	***115***	2514	693	1012	484	509	376	350	348	421
27-A-Wipe	<182	<91	205	<45.5	<45.5	<45.5	<45.5	<45.5	<36.4	<45.5	<45.5
28-A	<13700	***688***	4735	344	2135	<344	344	<344	275	<344	344
28-A-Wipe-1	<184	***91.6***	729	***45.9***	194	***45.9***	***45.9***	<45.9	***36.7***	<45.9	<45.9
28-A-Wipe-2	<187	***93.4***	1089	***46.8***	209	***46.8***	***46.8***	<46.8	***37.5***	<46.8	<46.8
28-A-Wipe-3	<179	***89.3***	877	***44.6***	200	***44.6***	***44.6***	<44.6	***35.7***	<44.6	<44.6
28-A-Wipe-4	***184***	***91.6***	1896	***46.0***	308	***46.0***	***46.0***	<46	***36.8***	<46	***46.0***
28-A-Wipe-5	<188	<94.4	1216	<47	***47.0***	<47	***47.0***	<47	***37.6***	<47	<47
28-B	<703	***352***	3934	1173	1223	716	708	176	141	176	176
29-A	<13400	***6720***	122976	16363	42672	3360	3360	<34	2688	<34	3360
31-A-Wipe	<44.1	<22.1	<11.0	<11.0	<11.0	***11.0***	***11.0***	<11	<8.84	<11	<11
31-B-Wipe	<116	<58.4	231	***29.1***	266	167	***29.1***	***29.1***	***23.3***	***29.1***	<29.1
32-A	101	***256***	2314	667	596	376	301	236	200	152	369
33-A	54.1	***27.1***	449	1042	774	1768	685	891	348	340	352
33-A-Wipe	<80.3	<40.3	95.4	123	177	308	130	197	***16.1***	***20.1***	106
33-B-1	362	***181***	3509	3437	3491	7652	3238	3455	2207	1917	2153
33-B-2	352	***1560***	7824	8422	5556	9653	4026	5275	2585	2426	2286
33-B-3	410	***1538***	8234	9320	5489	8808	4158	5715	2827	2765	2642
33-B-4	411	***1761***	9964	11217	5855	6328	3493	4849	2650	2527	2280
33-B-5	456	***1066***	6459	6322	3994	5295	2990	3948	2143	1851	1942
34-A	<1050	***230***	442	294	256	183	324	217	221	200	775
34-A-Wipe	<191	<95.7	<48.0	<48	<48.0	<48	<48	<48	<38.4	<48	***48.0***
34-B	<415	***1011***	1405	811	731	104	420	104	82.9	104	929
35-A-Wipe	<114	<56.9	<28.5	<28.5	<28.5	<28.5	<28.5	<28.5	<22.8	<28.5	<28.5
35-B-Wipe	<71.8	<36.1	<18.0	<17000	<18.0	<17000	<17000	<17000	<14.4	<17000	<17000
36-A	<340	<170	883	426	435	84.9	84.9	84.9	68.0	84.9	84.9
36-A-Wipe	<286	<143	<71.6	<71.6	***71.6***	<71.6	<71.6	<71.6	<57.3	<71.6	<71.6
36-C-Wipe	<90.1	<44.9	<22.5	<22.5	<22.5	<22.5	<22.5	<22.5	<18	<22.5	<22.5
36-D	<74.4	<37.2	179	<18.6	109	<18.6	18.6	<18.6	14.9	<18.6	<18.6
37-A	<155	***77.7***	823	283	356	38.8	204	38.8	130	38.8	38.8
37-B-Wipe	<14.6	<7.31	<3.65	<3.65	<3.65	<3.65	<3.65	<3.65	<2.92	<3.65	<3.65
37-C	<28	<14	<7.00	<7.00	<7.00	<7.00	<7	<7.00	<5.6	<7.00	<7.00
38-A	53.8	***133***	2856	160	487	70.2	159	13.4	66.2	13.4	64.5
39-A	<64.0	***1440***	16681	1781	2235	160	744	<160	128	<160	<160
39-B-Wipe	<60.5	<30.3	64.6	<15.2	***15.2***	<15.2	<15.2	<15.2	<12.1	<15.2	<15.2
40-A	<69.0	<34.5	246	72.5	135	17.3	77.2	***17.3***	13.8	<17.3	<17.3
40-B-Wipe	<60.7	<30.3	<15.2	<15.2	<15.2	<15.2	<15.2	<15.2	<12.1	<15.2	<15.2
41-A	<77.1	***38.6***	528	95.6	182	19.3	103	***19.3***	71.9	19.3	19.3
42-A	121	***60.7***	2075	300	507	156	215	***30.3***	137	30.3	30.3
42-A-Wipe	<143	<71.7	***35.9***	<35.9	<35.9	<35.9	<35.9	<35.9	<28.7	<35.9	<35.9

Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
43-A	<25700	<12900	27195	<6430	<6430	<6430	<6430	<6430	<5140	<6430	<6430
43-A-Wipe	<1240	<62.2	142	<31.1	<31.1	<31.1	<31.1	<31.1	<24.9	<31.1	<31.1
44-A-Wipe-1	<5050	***2523***	32010	***1260***	11731	<1260	***1260***	<1260	***1007***	<1260	<1260
44-A-Wipe-2	<5080	***2542***	27303	**1273**	7965	<1270	<1270	<1270	<1020	<1270	<1270
44-A-Wipe-3	***2448***	***1222***	20148	***612***	5818	<612	<612	<612	<49.7	<612	<612
44-A-Wipe-4	<1020	***512***	5781	***256***	2429	<256	<256	<256	<205	<256	<256
44-A-Wipe-5	<106	<525	2222	***264***	1563	<264	<264	<264	<211	<264	<264
47-D-Wipe	<427	<214	***107***	***107***	732	617	476	***107***	***85.5***	<10600	***107***
47-E-Wipe	<192	<96.4	246	***48.2***	435	***48.2***	275	***48.2***	272	203	662
48-A	<164000	***82089***	896818	41044	221229	<41000	<41000	<41000	<32800	<41000	<41000
49-A	<199	***99.5***	746	49.8	672	259	394	***49.8***	389	***495***	1144
50-A	1127	***1341***	5746	1115	3014	***812***	1601	*516*	2189	***1645***	3941
51-A	<12800	<6400	<3200	<3200	<4030	<3200	3198	<3200	2558	<3200	<3200
53-A	930	***947***	2869	1083	2937	***706***	2112	***1290***	9212	***23186***	50908
53-A-Wipe	<114	<57.3	<28.5	<28.5	<28.5	<28.5	<28.5	<28.5	<22.8	<28.5	***28.5***
54-A	243	***121***	1409	328	831	***60.7***	448	***60.7***	435	***309***	468
54-B-1	1664	***1941***	10380	1791	6149	***1212***	3605	***1450***	4033	*2647*	***4643***
54-B-2	1572	***1877***	9879	1778	6269	***1338***	4059	***1769***	4410	***2883***	***5200***
54-B-3	1526	***1769***	8809	1488	6141	***1208***	4344	***1582***	4625	***2940***	***5364***
54-B-4	375	***1669***	7783	1360	5833	***1247***	4154	***1763***	***4464***	***2748***	***4764***
54-B-5	1896	***2166***	11605	***1970***	8074	***1569***	5925	***1822***	***5762***	***3122***	***5484***
54-C	<55300	<27700	<13800	<13800	<13800	<13800	13831	<13800	***11065***	<13800	<13800
54-D	5026	***5927***	20317	***6508***	10510	***4865***	6378	*5454*	***43232***	***88449***	***107544***
56-A	<363	<182	769	***90.7***	482	***90.7***	482	***90.7***	***599***	***590***	***1541***
56-B	<75.0	***37.5***	397	***147***	278	***155***	299	***207***	***359***	***300***	***778***
57-A	<238	***119***	807	***474***	532	***362***	497	*385*	***417***	***421***	***1460***
57-A-Wipe	<367	<183	***91.7***	<91.7	<91.7	***91.7***	<91.7	***91.7***	***73.3***	***91.7***	***91.7***
57-B	184	***91.9***	951	***353***	619	***273***	331	218	***238***	***254***	***832***
57-C	<185	***92.5***	1526	***1175***	883	***825***	555	480	***449***	378	***985***
58-A	<359	<180	361	***90.0***	90.0	***90.0***	***611***	385	***456***	479	***1750***
59-A-1	<398	***199***	2408	***1107***	2229	***1357***	***2189***	1535	***2428***	1748	***4399***
59-A-2	<371	***186***	1399	***736***	1402	***915***	***1252***	842	***1030***	863	***2597***
59-A-3	<417	***208***	3188	***1973***	3042	***2834***	***2125***	2313	***2792***	2188	***4480***
59-A-4	420	***927***	3293	***1825***	3126	3021	***2769***	2769	***4342***	2706	***4951***
59-A-5	<373	***186***	2424	***1374***	2909	1626	***2424***	1755	***2461***	1635	***3990***
60-A-Wipe	<240	***12.4***	70.9	43.2	184	108	203	88.0	108	76.9	243
62-A	430	215	3293	***638***	1680	740	***892***	573	700	914	***11526***
63-A-Wipe	<912	<456	***228***	***228***	2285	1387	1073	***228***	***182***	***228***	1434
73-A	<125	<6220	3110	***3110***	3515	<3110	<3110	3110	2488	3110	<3110
74-A-Wipe	<249	<124	<62.1	<62.1	<62.1	<62.1	<62.1	<62.1	<490	<62.1	<62.1
74-B-Wipe	<77.1	<38.4	***19.3***	<19.3	***19.3***	<19.3	***19.3***	<19.3	***15.4***	<19.3	<19.3
76-A-Wipe	<23900	<11900	***60.0***	***60.0***	***60.0***	***60.0***	<60	***60.0***	***48.1***	***60.0***	***60.0***
76-B-Wipe	<13.1	<6.55	14.6	***3.28***	13.6	***3.28***	***3.28***	<3.28	***2.62***	<3.28	***3.28***
78-A	<133	66.4	782	1138	***557***	920	***406***	461	295	357	***1021***
78-B	<173	<86.5	405	286	***304***	237	***186***	43.3	34.6	43.3	***353***
79-A	<179	89.6	3091	905	***9050***	2598	***4738***	2419	5085	2811	9038
80-A-Wipe	<45.7	<22.8	<11.4	<11.4	<11.4	<11.4	<11.4	<11.4	<9.13	<11.4	<11.4

Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
80-B-Wipe	<41.9	<20.8	***10.4***	<10.4	***10.4***	<10.4	<10.4	<10.4	<8.35	<10.4	<10.4
81-A	<32000	<1600	800	800	***5584***	800	***4000***	800	3968	3532	8560
81-B	<58.8	29.4	691	14.7	***299***	14.7	***80.7***	14.7	11.8	14.7	62.9
81-C	<640	32.0	383	193	***197***	134	***137***	115	109	97.8	243
82-A-1	281	748	3741	1265	***2316***	2015	1677	1361	1637	2078	15254
82-A-2	256	128	2198	631	***1583***	960	1037	774	1016	1716	12444
82-A-3	289	144	2866	796	***1921***	1153	1144	864	1194	1850	13252
82-A-4	283	142	2826	897	***2512***	1104	1559	1007	1761	2333	15656
82-A-Wipe	<670	<335	***167***	<167	***167***	***167***	***167***	<167	***134***	<167	***167***
Foam Baffle 1	<2140	1074	6381	538	***538***	<538	<538	<538	<429	<538	<538
Foam Baffle 2	<2100	1052	***3870***	<527	***527***	<527	<527	<527	<421	<527	<527
Foam Baffle 3	<2090	1045	***5020***	<522	***522***	<522	<522	<522	<418	<522	522
Foam Baffle 4	<2270	1131	***3468***	<566	***566***	<566	<566	<566	<453	<566	<566
Foam Baffle 5	<2400	1200	***3466***	<600	***600***	600	<600	<600	<481	<600	600
Foam Baffle 6	<2230	1114	***2755***	<558	***558***	<558	<558	<558	<446	<558	<558
Foam Baffle 7	<2440	1217	***2496***	<609	<609	<609	<609	<609	<487	<609	<609
Foam Baffle 8	<24.9	1197	*599*	<599	<599	<599	<599	<599	<479	<599	<599
Foam Baffle 9	<2330	1164	*583*	<583	<583	<583	<583	<583	<466	<583	583
Foam Baffle Wipe 1	<5110	<2560	***1277***	<1280	<1280	<1280	<1280	<1280	<1020	<1280	<1280
Foam Baffle Wipe 2	<5050	<2520	<1260	<1260	<1260	<1260	<1260	<1260	<1010	<1260	<1260
Foam Baffle Wipe 3	<5050	<2520	<1260	<1260	<1260	<1260	<1260	<1260	<1010	<1260	<1260
Foam Baffle Wipe 4	<5000	<2500	<1250	<1250	<12510	<1250	<1250	<1250	<1000	<1250	<1250
Foam Baffle Wipe 5	<5020	<2500	<1260	<1260	<1260	<1260	<1260	<1260	<1000	<1260	<1260
Foam Baffle Wipe 6	<5090	<2540	<1270	<1270	<1270	<1270	<1270	<1270	<1020	<1270	<1270
Water Baffle 1	<3200	16017	***284395***	8018	203422	8018	48584	<8020	<6420	<8020	8018
Water Baffle 2	<30100	14542	***286890***	7280	218754	7280	49668	<7280	<5830	<7280	7280
Water Baffle 3	<23200	11855	***239413***	5928	187492	5928	47161	<5930	<4740	<5930	5928
Water Baffle 4	<30200	15098	***301962***	7549	218286	7549	54026	<7550	<6040	<7550	7549
Water Baffle 5	<40200	<20000	79581	<10000	49894	<10000	10029	<10000	<8010	10029	44655
Water Baffle 6	<42400	<21200	68604	<10600	50933	<10600	10602	<10600	<8470	<107	10602
Water Baffle 7	<39600	<19800	72325	<9910	44281	<9910	9914	<9910	<7920	9914	40591
Water Baffle 8	<42100	<21000	66525	<10500	10525	<10500	10525	<10500	<8420	<10500	10525
Water Baffle 9	<64200	<32200	84726	<16100	16053	<16100	16053	<16100	<12900	<16100	16053
Water Baffle Wipe 1	<93400	<46700	***23322***	<23300	<23300	<23300	<23300	<23300	<18700	<23300	<23300
Water Baffle Wipe 2	<90900	<45300	<22700	<22700	<22700	<22700	<22700	<22700	<18100	<22700	<22700

Table D4 (continued). Mass (ng) of Individual and Summed PFAS pre-TOP Assay for Each Component (PFSAs. FtSs, PFOSA, Sum)

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
01-A	1368	1279	6373	510	37957	<87.1	<87.1	<87.1	<349	85294	15016	87.1	157707.4
01-B	95.3	72.9	465	19.5	7521	<19.5	***19.5***	19.5	***77.9***	44828	8569	281	69398.93
01-C	273	340	2337	278	21903	***24.8***	<24.9	<24.9	<99.8	28344	5877	408	69185.41
01-D	242	310	1771	220	18127	<37.9	<37.9	<37.9	<152	24005	6056	298	55823.45
01-D-Wipe	<36.9	<37.2	<36.9	<36.9	36.9	<36.9	<36.9	<36.9	<148	18025	***126***	<36.9	18187.98
01-E	32.2	32.4	607	32.2	7632	<3200	<3200	<3200	<129	7826	2151	32.2	20659.56
02-A	620	546	2869	38.0	4294	<38	<38	<38	587	112294	22459	38.0	189756.3
02-B	296	354	1955	68.6	10867	<68.6	<68.6	<68.6	<274	68785	27617	68.6	122969.2
03-A-Wipe	<19.5	<19.6	135	<19.5	1138	<19.5	<19.5	<19.5	<78.1	3726	961	256	16436.37
04-A	<960	<970	960	<960	238080	<960	<960	<960	<3840	173280	105600	27696	616627.2
05-A-Wipe	61.4	79.0	458	85.1	8988	<6.95	<6.95	<6.95	***27.8***	35300	4413	186	53723.88
06-A	12286	21150	141564	25004	1527500	<1880	<1880	<1880	<7520	294220	54614	9823	2143313
07-A	<3410	<3450	<3410	<3410	124912	<3410	<3410	<3410	<1370	179518	117745	24982	478248.4
08-A	<18	<17200	17019	<18	472289	<173	<173	<173	<68100	61440	<57900	<18	567767.7
09-A-Wipe	<2.78	<2.8	2.78	<2.78	629	<2.78	<2.78	<2.78	<11.1	327	224	26.1	1547.723
09-B-Wipe	<3.46	***3.47***	35.3	***3.46***	1033	***3.46***	<3.46	<3.46	<13.9	1143	712	161	4813.363
09-C-Wipe	<4.05	<4.07	30.9	***4.05***	2039	<4.05	<4.05	<4.05	<16.2	810	516	141	4639.029
10-A	218	219	3288	218	47220	<22	<22	<22	<872	78518	23146	1385	175979.7
10-B	136	566	3300	136	31132	<136	<136	<136	<542	92312	22206	606	168594.6
11-A	<3590	<3620	14953	<3590	202244	<3590	<3590	<3590	<14300	118693	12192	<3590	355253.1
12-A	<5070	<5120	<5070	<5070	127673	<5070	<5070	<5070	<20300	18290	17226	<5070	163188.7
12-B	<5970	<603	<5970	<5970	257693	<5970	<5970	<5970	<2390	152409	20281	5965	448278.4
13-A	<9080	<9170	60687	9078	984968	<9080	<9080	<9080	<36300	296852	30865	<9080	1400606
13-B	8790	8878	79064	8790	944903	<8790	<8790	<8790	<35200	226777	29885	<8790	1324666
14-A-Wipe	<22	<22.1	22.0	<22	1499	<218	<218	<218	<87.9	***79.4***	***75.0***	***22.0***	1941.392
14-B-Wipe	<17.2	<17.4	17.2	<17.2	316	<17.2	<17.2	<17.2	<68.5	***62.0***	***58.4***	<17.2	673.6977
14-C	<1680	<17.2	<1680	<1680	49476	<1680	<1680	<1680	<6720	6065	5712	<1680	73701.6
14-D-Wipe	<25.1	<25.2	25.1	<25.1	732	<25.1	<25.1	<25.1	<101	***90.6***	***85.6***	***25.1***	1078.69

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
15-A	366	368	5034	366	40036	<366	<366	<366	<1470	93448	21896	366	184671.9
15-B	1578	1291	5299	310	57756	<310	<310	<310	<12400	42134	12869	2271	143679.5
15-C-Wipe	<21.9	<22	21.9	<21.9	348	<21.9	<21.9	<21.9	<87.5	2072	616	***21.9***	3288.996
15-D	<7.00	<7.07	57.8	**7.00**	812	<7	<7	<7.0	<28	7133	1778	396	10938.48
17-A-Wipe	<34	<34.2	<34.0	<34	215	<3360	<3360	<3360	<136	***123***	***116***	<34	453.9012
17-B-Wipe	<26.6	<26.8	122	<26.6	324	<26.6	<26.6	<26.6	<106	1726	<90.4	<26.6	2834.368
18-A	83.4	84.3	868	83.4	10596	<83.4	<83.4	<83.4	<334	48809	16854	83.4	81424.97
18-B	33.3	33.6	312	33.3	3345	<33.3	<33.3	<33.3	<133	29566	7695	33.3	42864.66
19-A	<950	960	23750	4095	380950	<950	<950	<950	<3800	162450	46075	14440	660801
20-A	105	106	1392	105	29261	<105	<105	<105	<422	26137	7447	430	67912.33
21-A	<7320	<7390	7320	7320	733428	<7320	<7320	<7320	<29300	234228	24887	<7320	1014502
21-A-Wipe	***36.3***	***36.5***	1446	695	62227	***36.3***	<36.3	<36.3	<145	31867	3059	341	101069.2
22-A	<4900	<4950	21935	<4900	326699	<4900	<4900	<4900	<19600	157590	16666	<4900	532694.2
23-A	14902	14976	105430	*14902*	1393320	<14900	<14900	<14900	<59600	391173	50666	<14900	2015174
23-B	5596	<5650	30608	***5596***	521508	<5600	<5600	<5600	<22400	137371	19025	<5600	730894.6
24-A-Wipe	***40.5***	199	1576	247	14174	<40.5	<40.5	<40.5	<162	6586	1477	***40.5***	25039.21
24-B-Wipe	653	908	4306	584	35635	<86.4	<86.4	<86.4	<344	14139	3404	530	62070.83
25-A-Wipe-1	***173***	1339	7451	923	54536	<175	<175	<176	<691	34071	10043	***173***	112781.5
25-A-Wipe-2	1539	2603	14363	1841	106912	<181	<181	<181	<724	80454	21868	1247	242267.7
25-A-Wipe-3	1010	1922	10853	1345	82074	<18	<18	<18	<707	51404	16091	1183	173553.4
25-A-Wipe-4	219	410	2279	314	18521	<33.2	<33.2	<33.2	<132	13985	6318	292	44485.85
25-A-Wipe-5	393	724	3926	545	31156	<71.8	<71.8	<71.8	<288	23488	8585	474	72802.82
26-A	<6270	<6330	<6270	<6270	169878	<6270	<6270	<6270	<25100	<22600	21313	<6270	191191.1
27-A	***486***	734	4834	***675***	56517	<57.5	<57.5	<57.5	<230	83685	20318	57.5	174357.5
27-A-Wipe	<45.5	<45.7	45.5	<45.5	3056	<45.5	<45.5	<45.5	<182	6326	***1545***	***45.5***	11222.84
28-A	***1955***	***2082***	13985	***2832***	276887	<344	<344	<344	<13700	73625	18706	344	399281.6
28-A-Wipe-1	***45.9***	***46.2***	307	***45.9***	10705	<45.9	<45.9	<45.9	<184	30936	1660	***45.9***	44981.82
28-A-Wipe-2	***46.8***	***47.1***	347	***46.8***	14062	<46.8	<46.8	<46.8	<187	24404	1824	***46.8***	42392.43
28-A-Wipe-3	<44.6	<44.9	209	***44.6***	14062	<44.6	<44.6	<44.6	<179	30301	1787	***44.6***	47784.95
28-A-Wipe-4	***46.0***	***46.3***	557	227	29394	<46	<46	<46	<184	47357	2495	193	83016.23

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
28-A-Wipe-5	<47	<47.2	47.0	<47	3184	<47	<47	<47	<188	10070	823	***47.0***	15518.55
28-B	***176***	***176***	3906	***176***	69432	<177	<177	<177	<703	80773	19308	176	182897.1
29-A	***3360***	***3394***	90048	*19454*	1468320	<34	<34	<34	<13400	2315040	500640	24394	4626149
31-A-Wipe	<11	<11.1	<11	<11	11.0	<11	<11	<11	<44.1	***39.9***	<37.6	<11	72.98716
31-B-Wipe	<29.1	<29.2	29.1	<29.1	442	<29.1	<29.1	<29.1	<116	3272	797	128	5471.379
32-A	***25.2***	***25.3***	439	***25.2***	2813	<25.2	<25.2	<25.2	101	26624	5283	190	41094.02
33-A	***126***	***127***	785	***13.6***	4989	<13.6	<13.6	<13.6	54.1	24573	9502	57.8	46957
33-A-Wipe	<20.1	<20.2	<20.1	<20.1	346	<20.1	<20.1	<20.1	<80.3	1923	465	***20.1***	3926.739
33-B-1	***503***	***532***	3473	***90.4***	32380	<90.4	<90.4	<90.4	<362	108897	45042	758	223277.2
33-B-2	***1002***	***1115***	6295	***733***	55912	<87.9	87.9	<87.9	352	174769	70681	691	361601.7
33-B-3	***766***	***909***	5264	***678***	48134	<102	<102	<102	<41.9	111016	52231	770	271674.7
33-B-4	***699***	***1370***	11484	***1674***	111352	<103	103	<103	411	183259	61840	853	424379.3
33-B-5	***507***	***577***	3948	***502***	39256	<114	<114	<114	456	165011	59568	514	306805.5
34-A	***26.4***	***26.4***	230	<26.4	1223	<26.4	<26.4	<26.4	<1050	14015	2786	26.4	21475.58
34-A-Wipe	<48	<48.2	<48.0	<48	48.0	<48	<48	<48	<191	***172***	***163***	<48	431.2829
34-B	***104***	***104***	757	<104	6569	<104	<104	<104	<415	51567	5183	104	70086.96
35-A-Wipe	<28.5	<28.6	<28.5	<28.5	28.5	<28.5	<28.5	<28.5	<114	***103***	<96.8	<28.5	131.206
35-B-Wipe	<17000	<18.1	<18.0	<17000	18.0	<17000	<17000	<17000	<71.8	***64.7***	<61.2	<17000	82.666
36-A	***84.9***	***85.5***	798	***84.9***	7161	<84.9	<84.9	<84.9	<340	16336	3704	<84.9	30491.39
36-A-Wipe	<71.6	<72.1	<71.6	<71.6	71.6	<71.6	<71.6	<71.6	<286	***258***	<243	<71.6	401.3611
36-C-Wipe	<22.5	<22.6	<22.5	<22.5	<22.5	<22.5	<22.5	<22.5	<90.1	<81.2	<76.5	<22.5	0
36-D	<18.6	<18.8	18.6	<18.6	275	<18.6	<18.6	<18.6	<74.4	1021	63.2	<18.6	1700.412
37-A	***38.8***	***39.1***	718	***38.8***	8309	<38.8	<38.8	<38.8	<155	15025	4900	38.8	31136.26
37-B-Wipe	<3.65	<3.68	<3.65	<3.65	<3.65	<3.65	<3.65	<3.65	<14.6	<13.2	<12.4	<3.65	0
37-C	<7.00	<7.07	<7.00	<7.00	<7.00	<7	<7	<7.0	<28	<25.3	<23.8	<7.00	0
38-A	<13.4	<13.5	96.1	***13.4***	1020	<13.4	<13.4	<13.4	53.8	18463	2614	64.8	26401.2
39-A	<160	***161***	3693	***1313***	127458	<160	<160	<160	<64	370065	42918	2729	571506.1
39-B-Wipe	<15.2	<15.2	15.2	<15.2	428	<15.2	<15.2	<15.2	<60.5	1866	***51.5***	<15.2	2440.758
40-A	<17.3	<1700	17.3	<17.3	526	<17.3	<17.3	<17.3	<69	2204	728	17.3	4072.828
40-B-Wipe	<15.2	<15.2	<15.2	<15.2	15.2	<15.2	<15.2	<15.2	<60.7	<54.7	<51.5	<15.2	15.17427

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
41-A	***19.3***	***19.4***	445	***19.3***	4609	<19.3	<19.3	<19.3	<77.1	15831	4146	108	26294.37
42-A	***152***	***183***	1035	***133***	9951	<30.3	<30.3	<30.3	<121	45934	11711	198	72960.39
42-A-Wipe	<35.9	<36	<35.9	<35.9	35.9	<35.9	<35.9	<35.9	<143	2539	***122***	<35.9	2732.248
43-A	<6430	<6490	6429	<6430	142723	<6430	<6430	<6430	<25700	409204	21858	<6430	607408.6
43-A-Wipe	<31.1	<31.3	<31.1	<31.1	398	<31.1	<31.1	<31.1	<1240	***112***	***106***	<31.1	758.2909
44-A-Wipe-1	19395	21278	99044	11392	645857	<1260	<1260	<1260	<5050	316338	37283	***1260***	1201637
44-A-Wipe-2	12220	12842	57430	6553	402955	<1270	<1270	<1270	<5080	227839	27680	<1270	786601.1
44-A-Wipe-3	8285	9584	42743	4368	269264	<612	<612	<612	<2450	155345	17568	***612***	538017.7
44-A-Wipe-4	2316	2937	15177	2034	129548	<256	<256	<256	<1020	63079	7777	***256***	232101.8
44-A-Wipe-5	1674	2335	13407	1593	107329	<264	<264	<264	<106	54418	7344	<264	192147.2
47-D-Wipe	<10600	<10700	<10600	<10600	107	<10600	<10600	<10600	<427	***386***	***364***	***107***	3300.201
47-E-Wipe	<48.2	<48.4	48.2	<48.2	466	<48.2	<48.2	<48.2	<192	***174***	***164***	***48.2***	3137.763
48-A	***273355***	***277254***	1229277	***41044***	8393558	<41000	<41000	<41000	<164000	5848812	580777	***174849***	18060105
49-A	<49.8	***50.0***	644	***49.8***	19342	<49.8	<49.8	<49.8	<199	6033	3340	***6978***	40735.05
50-A	***750***	***953***	4974	***244***	15486	<37.7	<37.7	37.7	151	45404	18237	***5369***	114653.3
51-A	<3200	<3230	<3200	<3200	255668	<32.2	<32.2	<32.2	<12800	11544	87941	*3198*	364107.5
53-A	***418***	***502***	2367	***223***	24264	<176	<176	324	<697	29933	13776	***12784***	180768.2
53-A-Wipe	<28.5	<28.7	<28.5	<28.5	<28.5	<28.5	<28.5	<28.5	<114	<103	<97.2	***28.5***	57.07216
54-A	***60.7***	***61.1***	1000	***60.7***	27392	<60.7	<60.7	<60.7	<243	7519	3772	***301***	44879.11
54-B-1	***596***	***959***	6220	***407***	35894	<79.2	79.2	79.2	317	101424	39619	***14738***	239847.6
54-B-2	***661***	***997***	6978	***548***	47869	<89.8	89.8	89.8	359	98792	44726	***15268***	257412.4
54-B-3	***589***	***1020***	7134	***517***	49523	<93.6	93.6	93.6	<374	84535	40067	***13293***	236661.2
54-B-4	***625***	***1088***	7192	***460***	39479	<93.8	93.8	93.8	<375	52419	37322	***11815***	186747.5
54-B-5	***647***	***1038***	6930	***394***	27296	<81.7	81.7	81.7	327	114413	58351	***13076***	272028
54-C	<13800	<14000	<13800	<13800	868595	<13800	<13800	<13800	<55300	49930	264175	***13831***	1221428
54-D	3750	***3223***	15658	***1494***	111898	153	1096	2047	611	229907	90053	***73555***	837656.1
56-A	90.7	***91.4***	1031	***90.7***	16022	<90.7	<90.7	<90.7	<363	8343	3452	***90.7***	33948.31
56-B	18.7	***18.9***	304	***18.7***	4930	<18.7	<18.7	<18.7	<75	5736	1769	***169***	15922.32
57-A	<59.5	59.8	467	<59.5	5353	<59.5	<59.5	<59.5	<238	36283	7772	***263***	55671.95
57-A-Wipe	<91.7	<92.2	<91.7	<91.7	<91.7	<91.7	<91.7	<91.7	<367	***331***	***312***	<91.7	1173.975

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
57-B	46.0	46.2	1062	46.0	11124	<46	<46	<46	<184	13836	3397	***208***	34108.91
57-C	198	247	1586	237	18405	<46.2	<46.2	<46.2	<185	38936	10543	*46.2*	77548.26
58-A	<90	<90.4	90.0	<90	2995	<90	<90	<90	<359	5275	1295	***90.0***	14056.26
59-A-1	99.5	100	1654	99.5	20103	<99.5	<99.5	<99.5	<398	33836	12679	***430***	88599.42
59-A-2	92.8	93.3	1180	92.8	14636	<92.8	<92.8	<92.8	<371	21518	7086	***93***	56012.7
59-A-3	104	105	1994	104	42506	<104	104	<104	<417	41047	13835	*783*	125725.7
59-A-4	105	106	1726	105	28320	<105	105	<105	<420	48248	16719	*789*	126371.4
59-A-5	93.2	93.8	1671	93.2	26663	<93.2	<93.2	<93.2	<373	37290	11243	***442***	98372.86
60-A-Wipe	<6.22	<6.25	<6.22	<6.22	34.1	<6.22	<6.22	<6.22	<240	924	238	30.1	2363.865
62-A	108	108	***957***	108	8635	<108	<108	<108	<430	25944	3838	108	61407.91
63-A-Wipe	<228	<229	<228	<228	996	<228	<228	<228	<912	***821***	***774***	<228	9864.615
73-A	<3110	<3140	***3110***	<3110	101864	<3110	<3110	<3110	<125	11228	10575	3110	148333.3
74-A-Wipe	<62.1	<62.4	<62.1	<62.1	62.1	<62.1	<62.1	<62.1	<249	<224	<211	<62.1	62.13434
74-B-Wipe	<19.3	<19.3	<19.3	<19.3	221	<19.3	<19.3	<19.3	<77.1	***69.5***	<65.3	<19.3	363.7415
76-A-Wipe	<60	<60.4	60.0	<60	460	<60	<60	<60	<23900	***216***	<204	<60	1204.805
76-B-Wipe	<3.28	<3.3	3.28	<3.28	13.3	<3.28	<3.28	<3.28	<13.1	***11.8***	<11.2	***3.28***	75.54843
78-A	33.3	33.4	***494***	33.3	4577	<33.3	<33.3	<33.3	<133	14409	2381	185	28150.3
78-B	<43.3	<43.5	***239***	<43.3	3076	<43.3	<43.3	<43.3	<173	10901	2236	43.3	18388.61
79-A	<44.8	45.0	***668***	182	24528	<11.4	44.8	<44.8	<179	16206	28000	5152	114650.8
80-A-Wipe	<11.4	<11.5	<11.4	<11.4	11.4	<11.4	<11.4	<11.4	<45.7	<41.1	<38.8	<11.4	11.41468
80-B-Wipe	<10.4	<10.5	<10.4	<10.4	96.9	<10.4	<10.4	<10.4	<410	***37.6***	***35.4***	<10.4	190.8855
81-A	<800	<808	<800	<800	20800	<800	<800	<800	<32000	22880	20240	5620	98384
81-B	<14.7	14.8	***232***	61.0	3897	<14.7	<14.7	<14.7	<58.8	2684	369	164	8656.306
81-C	16.0	16.1	***223***	<16	1026	<16	<16	<16	<640	5460	812	16.0	9210.123
82-A-1	70.1	70.4	***457***	<70.1	4231	<70.1	<70.1	<70.1	<281	14497	3518	287	55501.99
82-A-2	63.7	64.1	***1073***	63.7	9701	<63.7	<63.7	<63.7	<256	26824	4941	311	65784.85
82-A-3	72.0	72.4	***1172***	72.0	10569	<72	<72	<72	<289	25907	4815	420	68572.72
82-A-4	325	372	***2050***	70.9	18774	<70.9	<70.9	<70.9	<283	33645	7110	796	93222.76
82-A-Wipe	<167	<168	167	<167	3027	<167	<167	<167	<670	***603***	***568***	<167	5335.624
Foam Baffle 1	538	<540	***4223***	<538	102012	<538	<538	<538	<2140	60591	14343	<538	190236.5

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
Foam Baffle 2	<527	<529	***527***	<527	41053	<527	<527	<527	<2100	38176	8799	<527	94003.84
Foam Baffle 3	<522	<524	***522***	<522	53081	<522	<522	<522	<2090	59095	13074	<522	132879.6
Foam Baffle 4	<566	<569	***566***	<566	38457	<566	<566	<566	<2270	47826	10936	<566	102950.9
Foam Baffle 5	<600	<602	***600***	<600	42525	<600	<600	<600	<2400	48933	***9685***	<600	108209.8
Foam Baffle 6	<558	<561	***558***	<558	154906	<558	<558	<558	<2230	49899	***17821***	<558	227611.2
Foam Baffle 7	<609	<611	***609***	<609	124662	<609	<609	<609	<2440	50515	***16986***	<609	196484.5
Foam Baffle 8	<599	<602	***599***	<599	154616	599	<599	<599	<24.9	44303	***16205***	<599	218118.6
Foam Baffle 9	<583	<585	***583***	<583	125143	<583	<583	<583	<2330	43872	***16686***	<583	188611.8
Foam Baffle Wipe 1	<1280	<1280	<1280	<1280	9021	<1280	<1280	<1280	<5110	***4601***	<4340	<1280	14899.19
Foam Baffle Wipe 2	<1260	<1270	<1260	<1260	9061	<1260	<1260	<1260	<5050	***4541***	<4280	<1260	13601.59
Foam Baffle Wipe 3	<1260	<1270	<1260	<1260	9525	<1260	<1260	<1260	<5050	***4541***	<4280	<1260	14065.74
Foam Baffle Wipe 4	<1250	<1260	<1250	<1250	11119	<1250	<1250	<1250	<5000	***4520***	<4260	<1250	15639.81
Foam Baffle Wipe 5	<1260	<1260	<1255.22088	<1260	9344	<1260	<1260	<1260	<5020	***4520***	<4280	<1260	13863.93
Foam Baffle Wipe 6	<1270	<1280	<1270	<1270	28858	<1270	<1270	<1270	<5090	***4581***	***4319***	<1270	37757.53
Water Baffle 1	<8020	<8060	<80120	<8020	***8018***	<8020	<8020	<8020	<3200	5608910	***404868***	<8020	6598270
Water Baffle 2	<7280	<7320	7280	<7280	***7280***	<7280	<7280	<7280	29048	5253675	***415991***	<7280	6304966
Water Baffle 3	<5930	<5960	<59230	<5930	*5928*	<5930	<5930	<5930	23653	***5293045***	***333159***	<5930	6159489
Water Baffle 4	<7550	<7590	7549	<7550	***7549***	<7550	<7550	<7550	<30200	***4784101***	***332886***	<7550	5744104
Water Baffle 5	<10000	<10100	10029	<10000	***10029***	<10000	<10000	<10000	<40200	***4714977***	***264438***	<10000	5193659
Water Baffle 6	<107	<107	10602	<107	***10602***	<107	<107	<107	<42400	***4027896***	***244532***	<10600	4434375
Water Baffle 7	<9910	<9960	9914	<9910	***9914***	<9910	<9910	<9910	<39600	***4182082***	***230014***	<9910	4608949
Water Baffle 8	<10500	<10600	10525	<10500	***10525***	<10500	<10500	<10500	<42100	***4157828***	***248430***	<10500	4525406
Water Baffle 9	<16100	<16200	16053	<16100	***16053***	<16100	<16100	<16100	<64200	5152935	260124	<16100	5578052
Water Baffle Wipe 1	<23300	<23400	<23300	<23300	<233200	<23300	<23300	<23300	<93400	1296486	<79300	<93400	1319808
Water Baffle Wipe 2	<22700	<22800	<22700	<22700	<22700	<22700	<22700	<22700	<90900	***81845***	***77137***	<22700	158982.4

Table D5. Mass (ng) of individual and summed PFAS post-TOP Assay for each component (PFCAs)

Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
01-A	***17532***	***43831***	***22871***	***4383***	***18058***	***4383***	***4383***	***4383***	***3506***	***4383***	<4380
01-B	<48600	41301	30490	23991	24234	14091	14698	<12100	<9720	<12100	<12100
01-C	<54700	27336	13668	13668	13668	<13700	<13700	<13700	<10900	<13700	<13700
01-D	<33000	165	361	82.4	340	82.4	82.4	82.4	65.8	<8240	<8240
01-D-Wipe	***2338***	***2663***	***1624***	***426***	***62.6***	<6260	<6260	<6260	<50300	<6260	<6260
01-E	<25800	21126	15168	8051	<6440	<6440	<6440	<6440	<5150	<6440	<6440
02-A	<70200	35092	17546	17546	17546	<17500	17546	<70200	<14000	<17500	<17500
02-B	16450	25730	28732	16784	14760	11364	10060	4760	3259	2427	2779
03-A-Wipe	3618	5729	6191	4153	7652	3457	2661	1057	1084	465	957
04-A	<448000	<192000	96000	96000	96000	<96000	<96000	<96000	<76800	<96000	<96000
05-A-Wipe	61096	102099	54987	9260	4372	3218	2688	1670	1901	1439	1846
06-A	<823000	***376000***	***804640***	***188000***	<188000	<188000	<188000	<188000	<150000	<188000	<188000
07-A	<137000	***68258***	***165184***	***34129***	***34129***	***34129***	***34129***	<34100	<27300	<34100	<34100
08-A	<681000	<340000	170194	<170000	<170000	<170000	<170000	<170000	<136000	<170000	<170000
09-A-Wipe	***48.5***	***220***	***339***	***202***	***330***	***131***	***101***	***12.2***	***9.75***	***12.2***	***12.2***
09-B-Wipe	532	751	1364	823	1264	745	657	272	263	110	113
09-C-Wipe	***70.8***	***319***	***166***	***17.7***	***17.7***	***17.7***	***17.7***	***17.7***	***14.2***	***17.7***	***17.7***
10-A	***21811***	***63523***	***60524***	***32907***	***29335***	***29581***	***28245***	***21811***	***19466***	***21811***	***21811***
10-B	13550	45394	46241	23222	21173	20732	17057	3388	12653	3388	3388
11-A	***143435***	***71718***	***218021***	***35859***	***35859***	***35859***	***35859***	***35859***	***28687***	<35900	<35900
12-A	<203000	<101000	***50664***	***50664***	***50664***	***50664***	***50664***	<50700	<40500	<50700	<50700
12-B	<239000	***119302***	***59651***	***59651***	***59651***	<59700	<59700	<59700	<47700	<59700	<59700
13-A	***351592***	***966878***	***685165***	***87898***	***87898***	<87900	<87900	<87900	<70300	<87900	<87900
13-B	363122	923237	650442	90780	90780	90780	90780	<90800	<72600	<90800	<90800
14-A-Wipe	***5890***	***10219***	***8077***	***2985***	***718***	***553***	***580***	***218***	***208***	***48.6***	***48.6***
14-B-Wipe	***3893***	***6344***	***4362***	***1438***	***199***	***37.9***	***37.9***	***37.9***	***139***	***37.9***	***37.9***
14-C	<67200	<33600	16800	<16800	16800	<16800	16800	<16800	<13400	<16800	<16800
14-D-Wipe	***6522***	***11201***	***7965***	***2803***	***486***	***390***	***405***	***53.8***	***43.1***	***53.8***	***53.8***
15-A	***322***	***1491***	***875***	***80.3***	***80.3***	***80.3***	<8030	<8030	<6460	<8030	<8030
15-B	***233***	***1133***	***1242***	***353***	***328***	***58.5***	***238***	***58.5***	***46.6***	<5850	***58.5***
15-C-Wipe	1085	1363	1190	373	363	49.2	49.2	49.2	39.4	<4920	<4920
15-D	2800	1400	5933	700	700	700	700	<700	<560	<700	<700
17-A-Wipe	<33400	16687	8343	8343	8343	<8340	<8340	<8340	<6670	<8340	<8340
17-B-Wipe	1795	2904	2213	1113	768	591	392	63.6	50.9	63.6	63.6
18-A	***36646***	***18323***	***59917***	***9162***	***9162***	***9162***	***9162***	<9160	***7329***	<9160	<9160
18-B	<13300	***6663***	***3331***	***3331***	***3331***	***3331***	<3330	<3330	<2670	<3330	<3330
19-A	<380000	<190000	95000	<95000	<95000	<95000	<95000	<95000	<76000	<95000	<95000
20-A	10544	24252	24397	10940	2636	2636	2636	2636	2109	<2640	<2640
21-A	63959	108482	56953	20491	9116	3887	2177	444	292	79.1	79.1
21-A-Wipe	292786	966192	523354	73196	73196	<73200	<73200	<73200	<58600	<73200	<73200
22-A	196069	537473	313955	49017	49017	<49000	<49000	<49000	<39200	<49000	<49000
23-A	2980365	1490182	745091	<745000	<745000	<745000	<745000	<745000	<596000	<745000	<745000

Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
23-B	223823	861719	478422	55956	55956	<56000	<56000	<56000	<44800	<56000	<56000
24-A-Wipe	***11009***	***16547***	***10021***	***3857***	***2222***	***1523***	***1345***	***181***	***771***	***181***	***765***
24-B-Wipe	30453	42673	26487	10236	6257	5073	896	896	717	896	896
25-A-Wipe-1	19331	29374	22678	9179	7505	5167	4908	2959	3407	3737	4492
25-A-Wipe-2	***83694***	***41901***	***20950***	***20950***	***20950***	<21000	<21000	<21000	<16700	<21000	<21000
25-A-Wipe-3	***85854***	***213824***	***150649***	***21382***	***21382***	***21382***	***21382***	<21400	<17100	<21400	<21400
25-A-Wipe-4	78294	39147	98273	19547	19547	<19500	<19500	<19500	<15700	<19500	<19500
25-A-Wipe-5	31210	45087	34719	14363	10961	8315	7397	4784	4876	6156	7127
26-A	548416	816513	1034963	748534	752353	867688	625561	533903	493421	271153	232198
27-A	***16393***	***28248***	***13615***	***3621***	***963***	***1056***	***753***	***479***	***699***	***662***	***1047***
27-A-Wipe	124555	287254	162699	31139	<31100	<31100	<31100	<31100	<24900	<31100	<31100
28-A	***35744***	***59514***	***31481***	***9163***	***2341***	***1651***	***1152***	***652***	***552***	***101***	***101***
28-A-Wipe-1	61600	107052	50260	11703	3366	2567	1996	1170	1170	588	602
28-A-Wipe-2	***37015***	***62780***	***34656***	***8764***	***3157***	***2404***	***1697***	***827***	***811***	***441***	***449***
28-A-Wipe-3	125196	223176	104330	23497	6741	5389	3638	2041	2023	1225	1016
28-A-Wipe-4	***25130***	***42730***	***22227***	***5298***	***1207***	***802***	***684***	***446***	***428***	***101***	***101***
28-A-Wipe-5	75163	132953	63279	14398	3974	3095	2161	1244	1226	663	558
28-B	***138586***	***228488***	***119776***	***41327***	***5532***	***5532***	***5532***	***5532***	***4426***	***5532***	***5532***
29-A	***1344000***	***7190400***	***3685920***	***336000***	***336000***	<336000	<336000	<336000	<269000	<336000	<336000
31-A-Wipe	***97.8***	***48.9***	***166***	***162***	***184***	***154***	***126***	***24.5***	***19.5***	***24.5***	***24.5***
31-B-Wipe	1112	1557	1775	908	1043	575	361	265	51.9	64.9	64.9
32-A	5903	20307	26033	11806	11688	9268	9209	1476	1181	1476	1476
33-A	1105	1795	1408	834	768	799	570	407	218	43.4	175
33-A-Wipe	<10300	5157	2579	2579	2579	2579	2579	<2580	<2060	<2580	<2580
33-B-1	***95327***	***152647***	***136006***	***73550***	***60196***	***61223***	***68619***	***28146***	***19969***	<20500	<20500
33-B-2	<91300	111376	112061	67556	51124	43136	48385	<22800	<18300	<22800	<22800
33-B-3	<72400	85019	77241	42871	56077	43233	42871	20079	17112	<18100	<18100
33-B-4	93811	146656	113884	70461	65545	55099	66979	27037	19500	<20500	<20500
33-B-5	83165	136615	104264	60835	52571	49055	44835	23385	16844	<17600	<17600
34-A	4586	7181	5046	1819	641	568	490	106	85.1	106	106
34-A-Wipe	4966	7594	7985	5539	7062	6679	7003	2811	2445	1464	1863
34-B	10858	17323	16287	9795	10793	9225	10404	4315	3874	2889	3252
35-A-Wipe	<30300	31514	25522	14070	10163	8116	8950	<7580	<6070	<7580	<7580
35-B-Wipe	161	753	446	40.0	40.0	<4000	40.0	<4000	<32100	<4000	<4000
36-A	631	3596	2238	158	158	<15800	<15800	<15800	<126000	<15800	<15800
36-A-Wipe	<68000	<34000	16990	<17000	16990	<17000	<17000	<17000	<13600	<17000	<17000
36-C-Wipe	1065	1182	858	496	300	248	49.9	49.9	39.8	<4990	<4990
36-D	<7440	<3720	<1860	<1860	<1860	<1860	<1860	<18600	<1490	<18600	<18600
37-A	<31100	15530	7765	7765	7765	7765	7765	<7770	6212	<7770	<7770
37-B-Wipe	***281***	***448***	***313***	***98.7***	<800	<800	<800	<800	<643	<800	<800
37-C	<2800	<1400	<700	<700	<700	<700	<700	<700	<560	<700	<700
38-A	<13400	***6720***	***3360***	***3360***	<3360	<3360	<3360	<3360	<2690	<3360	<3360
39-A	<13800	<6900	<3450	<3450	<3450	<3450	<3450	<3450	<2760	<3450	<3450
39-B-Wipe	8059	13117	5397	1450	257	149	33.2	33.2	26.6	<3320	<3320

Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
40-A	744178	1000875	690734	124866	30042	14365	10600	1620	1433	<1800	<1800
40-B-Wipe	<13500	***67.8***	***33.9***	<339	<339	<339	<339	<339	<2710	<339	<339
41-A	***15426***	***7713***	***16063***	***3857***	<3860	<3860	<3860	<3860	<3090	<3860	<3860
42-A	***318***	***159***	***609***	***79.7***	***79.7***	<797	<797	<797	<6380	<797	<797
42-A-Wipe	24272	57403	34132	6068	6068	<6070	<6070	<6070	<4850	<6070	<6070
43-A	***1963***	***2418***	***1297***	***403***	***69.0***	***69.0***	***69.0***	***69.0***	***54.8***	<6900	***69.0***
43-A-Wipe	1051136	1642600	748974	64290	<64300	<64300	<64300	<64300	<51400	<64300	<64300
44-A-Wipe-1	1124130	1312427	879345	267381	56677	56677	56677	56677	45379	56677	56677
44-A-Wipe-2	***250434***	***1018684***	***634559***	***62326***	***62326***	***62326***	<62300	<62300	<49900	<62300	<62300
44-A-Wipe-3	271147	738122	487688	67975	67975	<68000	<68000	<68000	<54400	<68000	<68000
44-A-Wipe-4	***187167***	***263615***	***162123***	***53853***	***27115***	***17832***	***11957***	***2598***	***2071***	***2598***	***2598***
44-A-Wipe-5	106764	164571	109212	35400	21466	14687	2674	2674	2147	2674	2674
47-D-Wipe	18596	33711	26661	11920	5927	3988	3063	1115	185	231	231
47-E-Wipe	***12439***	***21672***	***18270***	***10884***	***7823***	***2983***	***2255***	***876***	***896***	***427***	***862***
48-A	***7182751***	***10999871***	***7203273***	***2815639***	***1457072***	***1282634***	***847565***	***443278***	<328000	<410000	<410000
49-A	***23447***	***35139***	***49879***	***35264***	***29915***	***28982***	***21581***	***16357***	***14553***	***7239***	***6636***
50-A	86474	120009	134327	84025	96647	97213	80445	47853	46911	22664	21119
51-A	<12800	***63957***	***195069***	***162291***	***134310***	***31979***	***31979***	<3200	<2560	<3200	<3200
53-A	***22676***	***115932***	***142577***	***162702***	***129255***	***132373***	***111397***	***63210***	***60092***	***42121***	***60092***
53-A-Wipe	31010	15505	50972	7752	7752	7752	7752	7752	6202	<7750	<7750
54-A	***4558***	***18415***	***12065***	***5932***	***5789***	***5347***	***4189***	***2644***	***2334***	***1140***	***1140***
54-B-1	32689	175705	224740	125854	128306	100520	76902	38819	33915	8172	8172
54-B-2	37446	135743	181614	94552	110466	89309	78075	43531	39506	9362	9362
54-B-3	37509	125656	166916	96586	104088	86459	69674	42761	35259	9377	9377
54-B-4	35924	172437	227222	120347	136513	105079	86308	48139	44636	8981	8981
54-B-5	31695	157682	202847	97462	109347	96669	77890	48255	48810	7924	7924
54-C	<553000	276623	138311	138311	138311	138311	138311	<138000	<111000	<138000	<138000
54-D	250742	125371	62686	62686	62686	62686	62686	62686	50148	62686	62686
56-A	3363	1681	6484	4256	5233	5843	6862	3457	3499	841	3909
56-B	<15000	<7500	3749	3749	3749	3749	3749	<3750	2999	<3750	<3750
57-A	816	408	1369	1195	1373	1186	860	205	164	205	205
57-A-Wipe	10799	16817	19465	10949	11658	9282	9225	4093	3099	2304	3084
57-B	<36800	31027	23535	11262	9653	<9190	11078	<9190	<7350	<9190	<9190
57-C	<37000	18497	9249	9249	9249	9249	9249	<9250	<7400	<9250	<9250
58-A	***3541***	***15347***	***15181***	***7602***	***7325***	***7004***	***7624***	***3972***	***3729***	***885***	***3674***
59-A-1	<74600	37290	18645	18645	18645	18645	18645	<18600	<14900	<18600	<18600
59-A-2	83344	41672	20836	20836	20836	20836	20836	20836	16669	<20800	<20800
59-A-3	<79600	39807	19904	19904	19904	19904	19904	<19900	15923	<19900	<19900
59-A-4	<83900	41955	20978	20978	20978	20978	20978	20978	16782	<21000	<21000
59-A-5	74201	37100	83847	18550	18550	18550	18550	<1860	14840	<1860	<1860
60-A-Wipe	1523	2603	2499	2812	2942	2239	1770	575	392	177	305
62-A	26177	38507	41749	39415	56141	33192	34877	14223	12447	8026	19007
63-A-Wipe	2015	1007	3584	3602	5584	4014	3077	504	401	504	504
73-A	124415	62207	152563	31104	31104	31104	31104	<31100	24883	<31100	<31100

Sample ID	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTrDA	PFTeDA
74-A-Wipe	3446	6000	4050	1270	136	<13600	<13600	<13600	<108000	<13600	<13600
74-B-Wipe	2986	5508	3950	1284	191	41.8	41.8	41.8	33.4	<418	<418
76-A-Wipe	***4130***	***6752***	***4462***	***1780***	***129***	***129***	***539***	***129***	***104***	***129***	***129***
76-B-Wipe	482	797	543	179	34.5	7.29	7.29	7.29	5.80	7.29	7.29
78-A	6623	9606	9888	7774	8960	6833	7100	3120	2470	1756	2805
78-B	<34600	<17300	***8652***	<8650	<8650	<8650	***8652***	<8650	<6920	<8650	<8650
79-A	8960	48496	61712	72576	82096	37296	29120	11211	12264	2240	13888
80-A-Wipe	***731***	***1085***	***825***	***256***	***25.4***	<2540	<2540	<2540	<2020	<2540	<2540
80-B-Wipe	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0
81-A	<32000	***16000***	***35200***	***35840***	***33440***	***8000***	***8000***	<8000	<6400	<8000	<8000
81-B	1471	4357	8548	1825	1783	368	368	368	294	<368	368
81-C	<128000	<6400	***3202***	<3200	<3200	<3200	<3200	<32000	<25600	<32000	<32000
82-A-1	***1500***	***5893***	***5678***	***4473***	***5437***	***3429***	***3187***	***375***	***300***	***375***	***375***
82-A-2	***27512***	***43103***	***40351***	***44020***	***65571***	***43332***	***47459***	***19350***	***16232***	***10753***	***21528***
82-A-3	***35439***	***56748***	***54056***	***59215***	***72897***	***51589***	***51813***	***21465***	***18684***	***12695***	***23551***
82-A-4	***17815***	***8907***	***37634***	***40528***	***59679***	***35852***	***38970***	***4454***	***14719***	***4454***	***23827***
82-A-Wipe	26922.08	36253	44014	47921	66049	43591	46080	15089.80	16545.26	9300.57	22968.98
Foam Baffle 1	11180	49644	27849	11321	2785	2785	2785	2785	2240	2785	<278000
Foam Baffle 2	87381	119266	187072	101507	152967	76282	87583	31481	33096	14792	15741
Foam Baffle 3	11200	39150	20988	2805	2805	2805	<281000	<281000	2240	2805	2805
Foam Baffle 4	***11079***	***36123***	***20786***	***2765***	***2765***	***2765***	***2765***	<276000	***2220***	<276000	***2765***
Foam Baffle 5	11099	38141	18828	2785	2785	2785	<278000	<278000	<22200	2785	<278000
Foam Baffle 6	11160	54285	36325	25427	13622	2785	2785	2785	2240	2785	2785
Foam Baffle 7	11135	41925	24232	8445	5494	2785	2775	2785	2233	2791.622	2784.895
Foam Baffle 8	***274169***	***583980***	***355049***	***68542***	***68542***	***68542***	***68542***	<68500	***54834***	***68542***	***68542***
Foam Baffle 9	295408	147704	310178	73852	73852	73852	<73900	73852	59082	73852	73852
Foam Baffle Wipe 1	24022	66455	53653	5998	5998	<6000	<6000	<6000	4804	<6000	5998
Foam Baffle Wipe 2	22923	95578	84184	5724	5724	<5720	<5720	<5720	4585	<5720	<5720
Foam Baffle Wipe 3	21441	84458	95571	5347	5347	<5350	<5350	<5350	<4280	<5350	<5350
Foam Baffle Wipe 4	261481	983170	475896	65370	<65400	<65400	<65400	<65400	52296	65370	65370
Foam Baffle Wipe 5	***559371***	***1143915***	***598527***	***139843***	<140000	<140000	<140000	<140000	***111874***	***139843***	***139843***
Foam Baffle Wipe 6	291270	646620	336417	72818	72818	<72800	<72800	<72800	58254	72818	72818
Water Baffle 1	195559	97780	294425	48890	48890	<4890000	<4890000	<4890000	<3910000	<4890000	<4890000
Water Baffle 2	200629	100315	232498	49976	<5000000	<5000000	<5000000	<5000000	<4020000	<5000000	<5000000
Water Baffle 3	198094	99047	263462	49433	48890	<5000000	<5000000	<5000000	<4020000	<5000000	<5000000
Water Baffle 4	<4990000	***2494697***	***1247348***	***1247348***	***1247348***	<1250000	<1250000	<1250000	<998000	<1250000	<1250000
Water Baffle 5	<5200000	***2598642***	***1299321***	***1299321***	***1299321***	<1300000	<1300000	<1300000	<1040000	<1300000	<1300000
Water Baffle 6	<4920000	***2460048***	***1230024***	***1230024***	***1230024***	<1230000	<1230000	<1230000	<984000	<1230000	<1230000
Water Baffle 7	<424000	211529	105765	<106000	105765	<106000	<106000	<106000	<84700	<106000	<106000
Water Baffle 8	<416000	208595	418676	<104000	104297	<104000	<104000	<104000	<83500	<104000	<104000
Water Baffle 9	<3950000	1974968	987484	987484	987484	<987000	<987000	<987000	<790000	<987000	<987000
Water Baffle Wipe 1	<2880000	***1442247***	***721123***	***721123***	***721123***	<721000	<721000	<721000	<577000	<721000	<721000
Water Baffle Wipe 2	<298000	***149344***	***663953***	<74800	***74763***	<74800	***74763***	<74800	<59700	<74800	<74800

Table D5 (continued). Mass (ng) of Individual and Summed PFAS Post-TOP Assay for Each Component (PFSAs. FtSs, PFOSA, Sum)

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
01-A	<4380	<4400	***4383***	<12100	***38746***	<4380	<4380	<4380	<17500	<15800	<14900	<4380	170843
01-B	<12100	<12300	<1140	<573	28121	<12100	<12100	<12100	<48600	<4390	<41300	<12100	176925
01-C	<13700	<13700	<13670	<858	13668	<13700	<13700	<13700	<54700	<49200	<46500	<13700	82007
01-D	<8240	<830	<8030	<188000	82.4	<8240	<8240	<8240	<33000	<29800	<28000	<8240	1344
01-D-Wipe	<6260	<6320	<62300	<31100	<6260	<6260	<6260	<6260	<251000	<22600	<213000	<6260	7114
01-E	<6440	<6510	28082	<49000	8953	<6440	<6440	<6440	<25800	<23300	<219000	<6440	81380
02-A	<17500	<17600	<170000	<1800	<17500	<17500	<17500	<17500	<70200	<63300	<59700	<17500	105275
02-B	<858	<863	2573	<278000	11947	<858	<858	<858	<3430	<3090	<2920	<858	151626
03-A-Wipe	<4310	<4310	43.1	<10600	1154	<4310	<4310	<4310	<17100	<15500	<14600	<4310	38221
04-A	<96000	<97000	<96000	<4890000	96000	<96000	<96000	<96000	<384000	<347000	<326000	<96000	384000
05-A-Wipe	68.2	75.6	456	94.9	8852	<1520	<1520	<1520	<6060	54.6	<5150	<1520	254177
06-A	<188000	<190000	***188000***	<3200	***1361120***	<188000	<188000	<188000	<752000	<679000	<639000	<188000	2917760
07-A	<34100	<34500	<339	<8340	***34129***	<34100	<34100	<34100	<137000	<123000	<116000	<34100	404086
08-A	<170000	<172000	<16990	<1770	170194	<170000	<170000	<170000	<681000	<614000	<579000	<170000	340388
09-A-Wipe	<1220	<1220	<12150	<573	***624***	<1220	<1220	<1220	<485	<43900	<4140	<1220	2042
09-B-Wipe	<155	<1560	15.5	<1240	988	<155	<155	<155	<618	<558	<5260	<155	7897
09-C-Wipe	<1770	<17800	<17580	<2050	***17.7***	<1770	<1770	<1770	<70.8	<6380	<6020	<1770	711
10-A	***21811***	***21811***	***21811***	***21811***	***47874***	***21811***	***21811***	***21811***	***21811***	***21811***	***21811***	***21800***	638603
10-B	<3390	<3420	3388	<8240	29269	<3390	<3390	<3390	<13600	<12200	<11500	<3390	242841
11-A	<35900	<36200	<3450	<8980	***221966***	<35900	<35900	<35900	<143000	<129000	<122000	<35900	863121
12-A	<50700	<51200	<50400	<18600	***50664***	<50700	<50700	<50700	<203000	<183000	<172000	<50700	303984
12-B	<59700	<60200	<5720	<23100	***239201***	<59700	<59700	<59700	<239000	<215000	<203000	<59700	537457
13-A	<87900	<88800	<8650	<281000	***872387***	<87900	<87900	<87900	<352000	<317000	<299000	<87900	3051817
13-B	<90800	<91700	<897000	<721000	914159	<90800	<90800	<90800	<363000	<328000	<309000	<90800	3214082
14-A-Wipe	<4860	<4860	<4450	<13600	***1495***	<4860	<4860	<4860	<19400	<17500	<1650	<4860	31042
14-B-Wipe	<3790	<3790	***37.9***	<9380	***291***	<3790	<3790	<3790	<15100	<13600	<12800	<3790	16893
14-C	<16800	<17000	<15820	<1370	16800	<16800	<16800	<16800	<67200	<60600	<57100	<16800	67200
14-D-Wipe	<5380	<5430	<5350	<19500	***772***	<5380	<5380	<5380	<21600	<1940	<18300	<5380	30748
15-A	<8030	<8090	<8000	<140000	***80.3***	<8030	<8030	<8030	<32200	<29000	<27400	<8030	3010
15-B	<5850	<5850	***58.5***	<22800	***338***	<5850	<5850	<5850	<23300	<21100	<19900	<5850	4146
15-C-Wipe	<4920	<49500	<49000	<15800	332	<4920	<4920	<4920	<19700	<17800	<16800	<4920	4893
15-D	<700	<707	<6900	<62700	700	<700	<700	<700	<2800	2527	<2380	<700	16160
17-A-Wipe	<8340	<8430	<8240	<276000	8343	<8340	<8340	<8340	<33400	<30100	<28400	<8340	50061
17-B-Wipe	<636	<636	<62700	<34100	<636	<636	<636	<636	<25400	<22900	<21500	<636	10017
18-A	<9160	<9250	<90000	<745000	***44617***	<9160	<9160	<9160	<36600	<33100	<31100	<9160	203479

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
18-B	<3330	<3360	<3320	<7920	***3331***	<3330	<3330	<3330	<13300	<12000	<11300	<3330	23320
19-A	<95000	<96000	<9250	<1300000	95000	<95000	<95000	<95000	<380000	<343000	<323000	<95000	190000
20-A	<2640	<2660	<2580	<5380	25742	<2640	<2640	<2640	<10500	<9520	<8960	<2640	108529
21-A	79.1	79.9	1559	613	63281	<7910	<7910	<7910	<31700	<28600	<27000	<7910	331573
21-A-Wipe	<73200	<73900	<73000	<72800	606798	<73200	<73200	<73200	<293000	<264000	<249000	<73200	2535523
22-A	<49000	<4950	<4890000	<15300	287731	<49000	<49000	<49000	<1960000	<177000	<167000	<49000	1433262
23-A	<745000	<753000	<74000	<74800	745091	<745000	<745000	<745000	<298000	<2690000	<2530000	<745000	5960729
23-B	<56000	<56500	<5530	<20500	482619	<56000	<56000	<56000	<2240	<202000	<190000	<56000	2158495
24-A-Wipe	<18100	***182***	***1523***	***181***	***14174***	<18100	<18100	<18100	<725	<6530	<61600	<18100	64481
24-B-Wipe	<896	902	4120	<281000	34484	<896	<896	<896	<35900	<3230000	<30500	<896	164985
25-A-Wipe-1	148	150	2468	148	18953	<14800	<14800	<14800	<594	<53600	<50500	<14800	134605
25-A-Wipe-2	<21000	<21100	<20840	<3770	***20950***	<21000	<21000	<21000	<83700	<75600	<71300	<21000	209397
25-A-Wipe-3	<21400	<21500	<20980	<4000	***143629***	<21400	<21400	<21400	<85900	<77200	<72900	<21400	679486
25-A-Wipe-4	<19500	<19700	<18650	<3320	101512	<19500	<19500	<19500	<78300	<70700	<66400	<19500	356320
25-A-Wipe-5	<7400	<7450	4185	<73900	30238	<7400	<7400	<7400	<29600	<26700	<25200	<7400	209418
26-A	<15300	<15400	15276	<1220	125800	<15300	<15300	<15300	<61100	<55100	<51900	<15300	7065779
27-A	<10000	<10000	<10000	<155	***2955***	<10000	<10000	<10000	<3980	<35900	<34000	<10000	70492
27-A-Wipe	<31100	<31300	<31100	<7050	31139	<31100	<31100	<31100	<125000	<112000	<106000	<31100	636785
28-A	<10100	<10200	***101***	***101***	***11068***	<10100	<10100	<10100	<40400	<36400	<34400	<10100	153721
28-A-Wipe-1	<10100	<10100	101	101	13699	<10100	<10100	<10100	<40200	<36200	<34100	<10100	255976
28-A-Wipe-2	<9800	<9890	***98.0***	<5000000	***13608***	<9800	<9800	<9800	<39200	<3540	<33400	<9800	166706
28-A-Wipe-3	<10200	<10200	614	102	28487	<10200	<10200	<10200	<40600	<36600	<3450	<10200	527475
28-A-Wipe-4	<10100	<10200	***101***	<208	***3148***	<10100	<10100	<10100	<40300	<363	<34200	<10100	102403
28-A-Wipe-5	<10200	<10200	357	102	15817	<10200	<10200	<10200	<40600	<36600	<34400	<10200	314990
28-B	<5530	<5590	<5380	<19900	***60580***	<5530	<5530	<5530	<22100	<20000	<18800	<5530	626378
29-A	<336000	<339000	<3360	<8030	***336000***	<336000	<336000	<336000	<1340000	<1210000	<1142000	<336000	13228320
31-A-Wipe	<2450	<2460	<23140	<4860	<2450	<2450	<2450	<2450	<9780	<8820	<8310	<2450	1032
31-B-Wipe	<649	<6530	<64300	<50400	477	<649	<649	<649	<25900	<23400	<22000	<649	8255
32-A	<1480	<1480	<140000	<1140	1476	<1480	<1480	<1480	<5900	<5320	<5020	<1480	101299
33-A	<4340	<4340	<418	<10600	348	<4340	<4340	<4340	<17300	<15600	<1470	<4340	8470
33-A-Wipe	<2580	<2600	<2540	<4990	2579	<2580	<2580	<2580	<10300	<9310	<8770	<2580	20628
33-B-1	<20500	<20800	<2050	<3450	***111147***	<20500	<20500	<20500	<82200	<74200	<69900	<20500	806831
33-B-2	<22800	<23100	46331	<4380	301264	<22800	<22800	<22800	<91300	<82400	<77600	<22800	781232
33-B-3	<18100	<18300	23878	<2450	29124	<18100	<18100	<18100	<72400	<65300	<61500	<18100	437506
33-B-4	<20500	<20700	<20480	<3390	60424	<20500	<20500	<20500	<81900	<73900	<69600	<20500	719394
33-B-5	<17600	<1780	<17550	<1860	48000	<17600	<17600	<17600	<70300	<63500	<59800	<17600	619569
34-A	<106000	<10700	<106000	<504	<106000	<106000	<106000	<106000	<42500	<38400	<36200	<10600	20735

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
34-A-Wipe	<208	<209	208	<3750	1447	<208	<208	<208	<832	<749	<707	<208	57066
34-B	<1300	<1300	<1250000	<700	7308	<1300	<1300	<1300	<5180	<4660	<4410	<1300	106322
35-A-Wipe	<7580	<7660	<75000	<90800	17179	<7580	<7580	<7580	<30300	<27400	<25800	<7580	115514
35-B-Wipe	<4000	<4030	<3860	<9800	<4000	<4000	<4000	<4000	<16100	<14500	<13600	<4000	1479
36-A	<15800	<15800	<1480	<1300	158	<15800	<15800	<15800	<63100	<57000	<5370	<15800	6940
36-A-Wipe	<17000	<17200	<16800	<1480	<17000	<17000	<17000	<17000	<68000	<61300	<57800	<17000	33980
36-C-Wipe	<4990	<4990	<4920	<16800	<4990	<4990	<4990	<4990	<1990	<1790	<16900	<4990	4290
36-D	<18600	<1880	<18550	<2580	<1860	<18600	<18600	<18600	<7440	<6710	<6320	<18600	0
37-A	<7770	<7840	<7750	<96000	7765	<7770	<7770	<7770	<31100	<28000	<26400	<7770	68333
37-B-Wipe	<800	<807	<797	<138000	<800	<800	<800	<800	<321	<2900	<2730	<800	1141
37-C	<700	<707	<700	<64300	<700	<700	<700	<700	<2800	***2527***	<2380	<700	2527
38-A	<3360	<3390	<3330	<8000	<3360	<3360	<3360	<3360	<13400	<12100	<11400	<3360	13440
39-A	<3450	<3490	<34100	<8650	<3450	<3450	<3450	<3450	<13800	<12500	<11700	<3450	0
39-B-Wipe	<3320	<3340	<32000	<7770	426	<3320	<3320	<3320	<13300	<12000	<11300	<3320	28947
40-A	<1800	<1800	1798	<2240	123571	<1800	<1800	<1800	<7170	<6460	<6090	<1800	2744083
40-B-Wipe	<339	<3410	<336000	<8170	<339	<339	<339	<339	<13500	<12200	<11500	<339	102
41-A	<3860	<3900	<3750	<9380	***3857***	<3860	<3860	<3860	<15400	<13900	<13100	<3860	46915
42-A	<797	<797	<7770	<106000	<797	<797	<797	<797	<31800	<28700	<27000	<797	1245
42-A-Wipe	<6070	<6130	<6000	<26700	6068	<6070	<6070	<6070	<24300	<21900	<20600	<6070	134010
43-A	<6900	<69000	<68500	<62300	***431***	<6900	<6900	<6900	<27500	<24800	<23400	<6900	6913
43-A-Wipe	<64300	<64900	<636	<35900	64290	<64300	<64300	<64300	<257000	<232000	<21900	<64300	3571290
44-A-Wipe-1	<5670	<57100	56677	<20800	723059	<5670	<5670	<5670	<228000	<205000	<192000	<5670	4748461
44-A-Wipe-2	<62300	<62700	<6070	<31100	***455678***	<62300	<62300	<62300	<250000	<224000	<21300	<62300	2546334
44-A-Wipe-3	<68000	<68200	<65400	<56700	346466	<68000	<68000	<68000	<271000	<245000	<232000	<68000	1979373
44-A-Wipe-4	***2598***	***2598***	***17493***	<5350	***141976***	<26000	<26000	<26000	<10400	<93400	<88100	<26000	898193
44-A-Wipe-5	<26700	<26900	13444	<5530	108270	<26700	<26700	<26700	<107000	<96400	<90900	<26700	586657
47-D-Wipe	<23100	<23400	<2240	<4450	<23100	<23100	<23100	<23100	<9250	<83500	<78700	<23100	105629
47-E-Wipe	<10600	<1070	<10590	<418	***513***	<10600	<10600	<10600	<424000	<38200	<36100	<10600	79900
48-A	***414547***	***435070***	***1670503***	<10000	***9973763***	<410000	<410000	<410000	<1640000	<1480000	<1396000	<410000	44725966
49-A	<1240	<1260	<1230000	<636	***20026***	<1240	<1240	<1240	<4980	<4490	<4230	<1240	289019
50-A	<3770	<3810	3768	<9360	17898	<3770	<3770	<3770	<15100	<13600	<12800	<3770	859353
51-A	<3200	<3230	<31100	<7400	***224649***	<3200	<3200	<3200	<12800	<115000	<10900	<3200	844233
53-A	<56700	<5730	<56000	<21000	***25397***	<56700	<56700	<56700	<22700	<20500	<19300	<56700	1067824
53-A-Wipe	<7750	<7830	<7580	<95000	55197	<7750	<7750	<7750	<31000	<28000	<26400	<7750	197648
54-A	<1140	<1140	<10630	<561	***7407***	<1140	<1140	<1140	<4560	<4110	<3870	<1140	70957
54-B-1	<8170	<8250	8172	<170000	8172	<8170	<8170	<8170	<32700	<29500	<27800	<8170	970139
54-B-2	<9360	<9460	9362	<1230000	53735	<9360	<9360	<9360	<37400	<33800	<31800	<9360	892063

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
54-B-3	<9380	<9470	9377	<1250000	40135	<9380	<9380	<9380	<37500	<33900	<31900	<9380	833175
54-B-4	<8980	<9070	8981	<410000	53437	<8980	<8980	<8980	<3590000	<32400	<3050000	<8980	1056985
54-B-5	<7920	<8000	7924	<104000	41758	<7920	<7920	<7920	<31700	<2860	<26900	<7920	936186
54-C	<138000	<140000	<1370	<885	846465	<138000	<138000	<138000	<553000	<499000	<470000	<138000	1814645
54-D	<62700	<63300	<6260	<32000	62686	<62700	<62700	<62700	<25100	226295	<213000	<62700	1216728
56-A	<841	<845	<8340	<278000	841	<841	<841	<841	<3360	<3030	<2860	<841	46269
56-B	<3750	<3790	<368	<9190	3749	<3750	<3750	<3750	<15000	<135000	<12700	<3750	25493
57-A	<2050	<2050	<19900	<3360	<2050	<2050	<2050	<2050	<81600	<73600	<69500	<2050	7986
57-A-Wipe	<5720	<575	573	<21000	5904	<5720	<5720	<5720	<2290	<2060	<1950	<5720	107252
57-B	<9190	<9290	15537	<897000	13744	<9190	<9190	<9190	<36800	<33200	<31300	<9190	115836
57-C	<9250	<9340	<9160	<987000	9249	<9250	<9250	<9250	<37000	33387	<31400	<9250	107376
58-A	<885	<890	***885***	<281000	***18091***	<885	<885	<885	<3540	<3190	<3010	<885	94861
59-A-1	<18600	<18800	<1860	<2640	18645	<18600	<18600	<18600	<74600	<67300	<63400	<18600	149162
59-A-2	<20800	<21000	<20540	<3750	20836	<20800	<20800	<20800	<83300	<75200	<70800	<20800	287538
59-A-3	<19900	<20100	<19550	<3330	19904	<19900	<19900	<19900	<79600	<71900	<67700	<19900	175152
59-A-4	<21000	<21200	<20950	<3790	20978	<21000	<21000	<21000	<83900	<75700	<71300	<21000	205580
59-A-5	<1860	<18700	<1770	<2540	18550	<1860	<1860	<1860	<74200	<67000	<63100	<1860	302738
60-A-Wipe	<1370	<1370	<13580	<841	13.7	<1370	<1370	<1370	<5450	<4910	<4630	<1370	17851
62-A	<1040	<1040	1037	<323	8829	<1040	<1040	<1040	<4150	<3730	<3530	<1040	333628
63-A-Wipe	<504	<50700	<5000000	<17600	504	<504	<504	<504	<20100000	<18100000	<17100000	<504	25298
73-A	<31100	<31400	<281000	<6900	31104	<31100	<31100	<31100	<124000	<112000	<106000	<31100	519587
74-A-Wipe	<13600	<13600	<1300000	<800	<13600	<13600	<13600	<13600	<54200	<48800	<46000	<13600	14902
74-B-Wipe	<418	<418	<4000	<10100	212	<418	<418	<418	<1670	<15000	<14200	<418	14290
76-A-Wipe	<12900	<1310	***129***	<700	***129***	<12900	<12900	<12900	<51900	<46800	<44100	<12900	18671
76-B-Wipe	<72800	<729	<721000	<68000	7.29	<72800	<72800	<72800	<2900	<2620	<2470	<72800	2085
78-A	<323	<325	323	<7750	4932	<323	<323	<323	<1290	<11600	<1100	<323	72190
78-B	<8650	<8740	<841	<278000	<8650	<8650	<8650	<8650	<34600	<31200	<29400	<8650	17304
79-A	<2240	<2260	<21380	<4310	27440	<2240	<2240	<2240	<8960	<8090	<7620	<2240	407299
80-A-Wipe	<2540	<2540	<2450	<4920	<2540	<2540	<2540	<2540	<10200	<9150	<8630	<2540	2923
80-B-Wipe	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0	0
81-A	<8000	<8080	<800	<140000	***8000***	<8000	<8000	<8000	<32000	<28900	<27200	<8000	144480
81-B	<368	<371	<35900	<9160	4448	<368	<368	<368	<1470	<1330	<1250	<368	24196
81-C	<32000	<32300	<3200	<7580	<3200	<32000	<32000	<32000	<128000	<1160	<109000	<32000	3202
82-A-1	<3750	<37800	<3750	<9250	***3027***	<3750	<3750	<3750	<15000	<13500	<127000	<3750	34049
82-A-2	<573	<575	***573***	<21400	***11830***	<573	<573	<573	<2290	<2070	<1950	<573	391614
82-A-3	<561	<563	***561***	<20500	***16755***	<561	<561	<561	<224000	<2020	<1910	<561	475469
82-A-4	<4450	<4480	<4340	<12900	***4454***	<4450	<4450	<4450	<17800	<16100	<15100	<4450	291293

Sample ID	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFDoS	4:2 FtS	6:2 FtS	8:2 FtS	PFOSA	Sum
82-A-Wipe	<573	<575	567	<22800	11013	<573	<573	<573	<2290	<2070	<1950	<573	598925
Foam Baffle 1	<278000	<281000	<278000	<5850	2785	<278000	<278000	<278000	<1120000	<10100	<950000	<278000	118943
Foam Baffle 2	<281000	<281000	<281000	<6440	332977	<281000	<281000	<281000	<1120000	<1010000	<957000	<281000	1240146
Foam Baffle 3	<281000	<281000	<278000	<6070	2805	<281000	<281000	<281000	<1120000	<1010000	<953000	<281000	90408
Foam Baffle 4	<276000	<278000	<2640	<5670	***11079***	<276000	<276000	<276000	<111000	<999000	<942000	<276000	95110
Foam Baffle 5	<278000	<278000	<276000	<5720	2785	<278000	<278000	<278000	<1110000	<1000000	<944000	<278000	81993
Foam Baffle 6	<278000	<281000	<278000	<6000	28253	<278000	<278000	<278000	<1120000	<1000000	<94800	<278000	185236
Foam Baffle 7	<281000	<281000	<281000	<6260	11230	<281000	<281000	<281000	<1120000	<1010000	<957000	<281000	301973
Foam Baffle 8	<68500	<6900	<68000	<59700	***68542***	<68500	<68500	<68500	<274000	<247000	<233000	<68500	1747829
Foam Baffle 9	<73900	<74300	<73000	<73200	73852	<73900	<73900	<73900	<295000	<266000	<251000	<73900	1329335
Foam Baffle Wipe 1	<6000	<6030	<59700	<26000	135068	<6000	<6000	<6000	<24000	1426916	20426	<6000	1749338
Foam Baffle Wipe 2	<573	<5750	<5670	<21000	108581	<573	<573	<573	<22900	1809682	19437	<573	2156418
Foam Baffle Wipe 3	<5350	<5370	<50700	<18600	39484	<5350	<5350	<5350	<21400	1082533	18173	<5350	1352355
Foam Baffle Wipe 4	<65400	<65800	<649	<50700	<65400	<65400	<65400	<65400	<261000	<235000	<222000	<65400	1968954
Foam Baffle Wipe 5	<140000	<141000	<140000	<1040	<140000	<140000	<140000	<140000	<559000	<505000	<475000	<140000	2833216
Foam Baffle Wipe 6	<729	<73300	<729	<68500	<72800	<729	<729	<729	<291000	<262000	<248000	<729	1623832
Water Baffle 1	<4890000	<4930000	<4860	<13700	<4890000	<4890000	<4890000	<4890000	<196000	<17600000	<16600000	<4890000	685544
Water Baffle 2	<5000000	<5030000	<5000000	<17500	<5000000	<5000000	<5000000	<5000000	<20100000	<18100000	<171000	<5000000	583418
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