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Destruction of PFAS in AFFF Using AirSCWO Supercritical Water Oxidation Technology

Prepared by: 374Water Inc.

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Introduction

Aqueous Film-Forming Foam (AFFF) is widely used for fire suppression, particularly in municipal, aviation, military, and petrochemical industries, due to its effectiveness in controlling high-intensity flammable liquid fires. However, AFFF contains per- and polyfluoroalkyl substances (PFAS), which are highly persistent chemicals linked to significant environmental and human health risks (EPA, 2022). The National Defense Authorization Act for Fiscal Year 2020 required DoD discontinue use of AFFF at its installations after October 1, 2024.Addressing the destruction of PFAS in AFFF waste, is essential to limit environmental contamination and adhere to stringent regulatory standards.

This white paper presents lab-scale tests and commercial scale field trials using the AirSCWO system—a supercritical water oxidation (SCWO) technology developed for high-efficiency PFAS destruction. After appropriately diluting the AFFF samples to adjust the caloric input. AFFF was then processed run through three AirSCWO systems: the lab-scale, the highly mobile AS-1 commercial scale system, and the mobile AS-6 commercial scale system. These systems demonstrated 99.9999%+ destruction efficacy of PFAS compounds within seconds. These tests position AirSCWO as a leading solution for complete and environmentally safe, commercial-scale, destruction of AFFF-related PFAS (374Water AirSCWO whitepaper, 2023).

Background on AFFF and PFAS

What is AFFF?

Aqueous Film-Forming Foam (AFFF) is a synthetic foam used extensively in firefighting to quickly extinguish fuel-based fires by creating a barrier between the fuel and oxygen. Its effectiveness in controlling fires is due to its unique chemical structure, which includes PFAS compounds that reduce surface tension, allowing the foam to spread across flammable liquids effectively (National Fire Protection Association, 2021).

Figure 1: Fire fighters training with Aqueous film-forming foam (AFFF)

Prevalence and Current Use of AFFF in the U.S.

Historically, AFFF has been widely adopted by the U.S. military, airports, and various industrial sectors. With limited options for safe disposal of PFAS-contaminated materials, substantial stocks of AFFF remain in use across the United States, and substantial quantities are held in reserve by the military and other agencies. Recent estimates indicate that millions of gallons of PFAS-containing AFFF remain in circulation, though replacement initiatives are underway (GAO, 2020).

Regulatory Trends and AFFF Buyback Programs

Growing concerns about PFAS contamination have led to regulatory actions aimed at limiting AFFF use and promoting safer disposal methods. The U.S. National Defense Authorization Act (NDAA) for 2020 mandated that the Department of Defense fully transition from AFFF to fluorine-free alternatives by October 2024.

Additionally, the EU's 2024 regulation on PFHxA enforces phased restrictions on PFAS in firefighting foams for public and aviation sectors.

In response, several states have initiated buyback programs to collect and destroy AFFF stocks. Destruction is critical to prevent environmental leaching of PFAS, which persist in water and soil, posing long-term risks to ecosystems and public health (EPA, 2021; Michigan PFAS Action Response Team, 2022).

These measures highlight the urgent need for advanced treatment and destruction solutions to responsibly manage AFFF stockpiles.

AirSCWO Technology for PFAS Destruction

AirSCWO harnesses the power of supercritical water oxidation (SCWO) to destroy organic waste streams resulting in clean water, mineral effluent and recoverable heat energy. SCWO is an advanced oxidation process that involves breaking down hazardous and non-hazardous organic compounds at elevated temperatures and pressures. AirSCWO eliminates recalcitrant organic wastes, including emerging contaminants, like PFAS in the SCWO process without creating harmful byproducts. The AirSCWO system was specifically developed for PFAS destruction, providing the following advantages:

- **Near-total PFAS Destruction**: AirSCWO achieves 99.99% destruction of PFAS in seconds (AirSCWO Systems, 2023).
- **High Efficiency**: Operates at 600°C, allowing rapid and complete destruction of even the most stable PFAS compounds (Savage, 1999).
- **Environmental Safety**: Converts hazardous compounds into benign byproducts like water and CO_2 with minimal residual waste.

Lab-Scale and Full-Scale System Trials

Lab-Scale AirSCWO

Initial lab-scale testing of the AirSCWO system focused on achieving high PFAS destruction rates using controlled conditions. The lab-scale setup achieved the following:

- **Destruction Efficiency**: Verified 99.99% destruction of PFAS compounds in AFFF within 20 seconds.
- **Temperature and Pressure**: Operated at 600°C and 3500 psi, optimal for breaking PFAS molecular bonds (Wang & Xu, 2019).
- **Scalability**: The success at this scale validated the progression to scale up to larger prototypes and full-scale systems.

AirSCWO 1: 1 Wet Ton Per Day System

The AirSCWO 1 (AS-1) was initially developed to provide essential data on operational efficiency and scalability for real-world AFFF waste management scenarios. The AirSCWO 1 has proven to be a highly mobile commercial-scale waste destruction unit utilized for smaller-scale demonstrations. Key results on this system include:

- **Performance**: Matched lab-scale destruction efficiency, achieving an overall 99.99% PFAS destruction efficiency (Total PFCA: 99.973%; Total PFSA: 99.996%; Precursors: 99.959%; Short chain (C<6): 99.991%; Total (Σ40 PFAS): 99.993%) at a maximum reactor temperature of 595°C (AirSCWO Systems, 2023).
- **Operational Feasibility**: Demonstrated consistent performance in an academic setting, proving effective destruction of waste as part of a demonstration contract for the US Environmental Protection Agency.

AirSCWO 6: 6 Wet Ton Per Day System

The AirSCWO 6 (AS-6) model was designed for continuous throughput of larger quantities of waste, particularly for mid-sized municipal use, federal agencies and industrial applications with high volumes of AFFF waste. Key results on this system include:

- **Industrial-Scale Performance**: Consistently achieved 99.99998% PFAS destruction at full capacity, operating with a maximum reactor retention time of 15 seconds at 595 °C to 605°C, processing large volumes of AFFF.
- **Environmental Compliance**: Outperformed regulatory requirements, producing discharge that met stringent water and soil standards for PFAS levels (EPA, 2021).

Regulatory Implications of Using AirSCWO for PFAS Destruction

Millions of gallons of AFFF that are stored at fire stations, airports and military bases around the country will require safe disposal, which includes destruction of PFAS. For example, the Department of Defense (DoD) uses AFFF in about 1,500 facilities and over 6,800 mobile sites worldwide to suppress fires. However, these stocks will need disposal as the National Defense Authorization Act for Fiscal Year 2020 required, in part, that DoD discontinue use of AFFF at its installations after October 1, 2024—with waivers possible until October 1, 2026, and an exemption for shipboard use.

AirSCWO technology aligns with the regulatory landscape's increased focus on PFAS mitigation. As states enforce more stringent regulations on PFAS levels in water and soil, technologies like AirSCWO play a critical role in compliance (Grand View Research, 2023; WEF, 2021), with a proven ability to destroy >99.9% of PFAS and an unprecedented ability to process AFFF at scale.

Conclusion

AirSCWO presents a revolutionary approach to PFAS destruction, offering unmatched efficiency and safety for treating AFFF. From lab-scale trials to full-scale

industrial applications, AirSCWO technology has consistently achieved 99.99% PFAS destruction in a matter of seconds (AirSCWO Systems, 2023). This technology not only meets but exceeds the performance requirements for PFAS treatment, providing an essential tool for AFFF buyback programs and regulatory compliance.

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