

PFAS-Containing AFFF Management & Remediation Processes including Conversion Services

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What is AFFF and How Is It Used



Aqueous Film Forming Foam (AFFF) is a very effective product for extinguishing chemical fires.

AFFF has been used for decades for both fire suppression and fire training in industry and defense agencies.

AFFF is typically used with a prescribed firefighting water supply mix to produce an oxygen-deprivation blanket over active flame fronts to extinguish flames and suppress further combustion of flammable materials.

AFFF as a fire suppressant is typically utilized in fixed fire suppression systems (i.e., buildings) or mobile firetruck delivery systems.

Techniques developed to effectively apply AFFF delivery systems typically include fire training facilities with or without secondary containment for firewater residuals to enable fluids recovery.

Actual AFFF firefighting scenarios or accidental discharges from fixed fire suppression systems, typically do not allow for immediate recovery of firewater residuals, allowing for potential PFAS contamination of soil, surface water, & groundwater.

PFAS releases to the environment may represent a significant potential human health and ecological threat in some scenarios.

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Presentation Outline

- ✓ Current State of Regulation for Existing AFFF Systems
- ✓ Plans, Methods and Procedures for AFFF Conversions
 - Engineering Design of AFFF Firefighting Systems
 - Construction and Procurement Contracting
 - Temporary Firefighting Management During Conversion
 - AFFF System Commissioning
 - Fire Training Drills
- ✓ Options for Treatment & Disposal of AFFF spills/releases
 - Offsite Disposal
 - Onsite Treatment
 - Novel Treatment Schemes
 - Emerging Treatment Technologies
 - New AFFF Formulations
 - Comparative Costs



Current Status of AFFF Management



Recent federal regulatory limits on PFAS substances in environmental systems (due to AFFF releases and other uses) include:

- ✓ Drinking water MCL of 4 ppt (PFOA & PFOS)
- ✓ CERCLA Hazardous Substance RQs for PFAS compounds
- ✓ TSCA Reporting Limits for PFAS compounds

- Potential threat of PFAS contamination of the environment from use or discharge of AFFF
- PFAS manufacturers and AFFF users doing extensive research and testing to prepare non-fluorinated AFFF substitutes (SFFF)
- Substitutes designed to duplicate PFAS-containing AFFF performance and cost with reduced environmental hazards
- US Dept of Defense has issued a new "Milspec" for PFAS-free foam fire suppressant agent
- US EPA and State equivalents have a primary responsibility to manage regulatory aspects of AFFF use during firefighting including human health risks, ecological impacts, and costs of environmental remediation
- To date in 2025, use of PFAS-containing AFFF has not been prohibited by federal or most state agencies
- Further AFFF regulations (federal and state) are expected in the near future
- Future prohibition or curtailment of use of PFAS-containing AFFF may be regulated by international mandates

PFAS-Containing AFFF Fixed System Cleaning & Conversion Plans

- AFFF has an effective "shelf-life" once manufactured and installed in a fixed fire suppression system
- PFAS containing AFFF fire suppression systems (e.g., airport hangars, chemical processing areas) are subject to current and pending regulations
 - Removal and disposal of existing inventory of bulk volumes of PFAS-containing AFFF
 - Fire system cleanings and/or conversions may be needed
- CLEANING:
 - Fire system cleaning (AFFF storage, mixing/proportioning equipment, piping, fire hoses) may provide lower cost solutions that allow longer term fire suppression asset service life
- CONVERSION:
 - Fire suppression system conversion allows for maximum flexibility to use new SFFF formulations, at higher capital costs
 - Implement team fire drills using SFFF to confirm performance at extinguishing fire under "real world" conditions.

Three Fundamental Pillars of AFFF Conversion

Assessment & Planning

- Evaluate risk and codes
- Assess system layout, functionality, viability, containment
- Understand usage
- Engage stakeholders
- Identify replacement
- Understand future risk
- Disposal / Treatment Coordination

Implementation

- Decontamination design removal and disposal
- Oversight
- Installation / upgrade / replacements / retrofit
- Monitoring systems
- Containment upgrades

Commissioning

- AHJ approvals
- Testing
- Training
- Monitoring
- Inspections
- Maintenance

AFFF Conversion - Assessment and Planning

- Review current system as-built drawings and design calculations
- Evaluate building codes and risks
- Conduct in field review of the system and operation
 - Meet with facility personnel and fire protection contractor (local knowledge)
 - Number of systems, volume of tanks, proportioners and system set-up
 - Discharge head configuration or generator configuration
- Obtain information on the current/former foam
 - Type and Manufacturer
 - Date of installation or reinstallation
 - Original or replacement (due to use or age)
 - Current testing/analytical (annual foam or chemical tests)
 - Annual testing/inspection records
 - Current inventory
- History of discharge(s) (could include testing)
- Containment systems or policy/BMPs

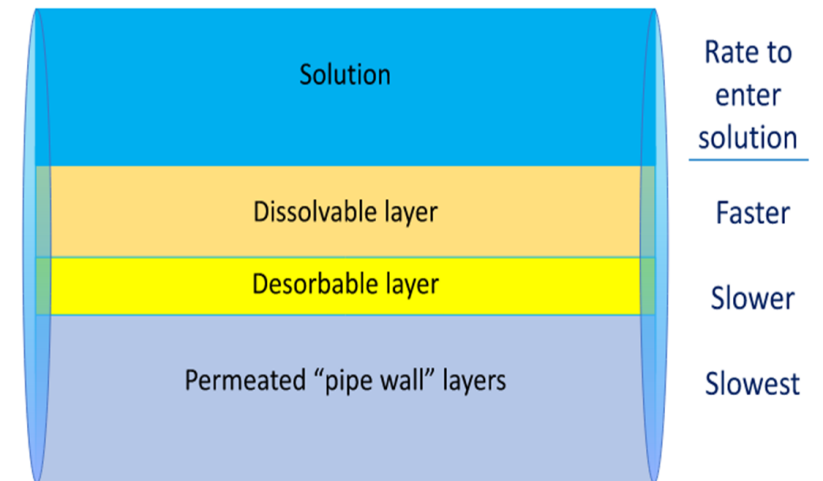


Fire Suppression System Cleaning

- Various guides but no approved cleaning methods
 - Triple-rinse with water (hot water) and/or mild detergent
 - Use of cleaning solvents
 - Physical/mechanical methods to assist removal of desorbed and permeated PFAS
- Temporary system modifications may be needed
- Anticipated down-time considerations for business operations
- Design collection, management, and disposal of wastes
- Manage rebound effects following initial cleaning
 - Future discharges managed as PFAS containing
 - Includes annual test/cleaning waters



PFAS persistence and rebound



- PFAS rebound originates in slowly desorbing layer(s), causing measured concentrations to increase with time.
- Rebounded PFAS concentrations can never be less than the PFAS levels in the water used for flushing.

Fire Suppression System Cleaning

- Fire suppression systems are complex assets
- Various studies and some guidance for mobile fire suppression system cleaning
- US EPA – recent study shows effectiveness of triple rinse in hangar fire suppression systems
- Recent studies of system cleaning include:
 - Water only rinse (triple-rinse)
 - Proprietary solution
 - Use of mild detergent – “over the counter”
- Comparative studies include water rinse vs. solvent/solution
 - Water rinse ~95% vs propriety solution >99% reduction of PFAS compounds in system after initial cleaning
 - Note that rebound of PFAS concentrations is likely to occur



Cleaning/Rinse Water Disposal Options and Challenges

- Offsite disposal - EPA guidance is referenced by local/state agencies for proper disposal
 - Thermal destruction (Incineration) – limited facility locations, may not destroy all short chain PFAS (air emissions potential)
 - Treatment/Landfill and Incineration – still have potential landfill leachate and air emission concerns
 - Treatment (solidification) and landfill disposal – landfill locations/space; permitting limitations
 - Deep well injection
- Onsite treatment – time, space, weather issues
 - Traditional/novel container-based technology options
 - With offsite disposal – POTW or other receiving facility
 - With onsite disposal sanitary sewer (POTW) or stormwater system – public perception – state/local jurisdictions may require applicable permits and approvals



Fire Suppression System Modification or Conversion



- Evaluate conversion to non-AFFF system (water or SFFF)
 - Identify Jurisdiction Having Authority (JHA), local, county, state FM/BI
 - Evaluate local fire protection laws and regulations
 - Evaluate NFPA codes
- Identify proper SFFF for current hazard and system design
- Cost-benefit of conversion vs. full system replacement
- Evaluate disposal vs cleaning costs of “to remain” components
 - Engineering costs
 - Construction and material costs
 - Disposal/recycling of potentially impacted piping
- Business impacts/disruption
- Temporary fire protection during cleaning/decommissioning
- If extensive nature of conversion, work may be considered repair and less/no permit or approvals needed by JHAs

Fire Suppression System Modification or Conversion

- Almost all conversions will require removal and disposal of old AFFF system components
- May require updates or change outs of other system components based on SFFF performance
- Determine disposal / treatment options for AFFF concentrate (including inventory) and rinse-waters from decontamination
- Disposal costs differ due to geography, system set-up, and risk tolerance/local regulations.
- Evaluate temporary fire protection measures that may be needed during conversion work



AFFF Disposal Options and Challenges

- Offsite disposal of solids and liquids
 - Geography (site and disposal facility)
 - Environmental Justice Concerns
 - Hazardous waste considerations (current and potential)
 - Thermal Destruction (Incineration)
 - Landfilling (Leachate generation)
 - Deep Well Injection (Public perception)
 - Liquids shipped for offsite treatment and disposal/discharge (transport on public hways)
 - Hub and spoke treatment facility (phased treatment at multiple locations)
- Onsite treatment (concentrate and rinse water)
 - Space, Time, Weather, Ability
 - Onsite or offsite discharge (storm/sanitary)
 - State or local jurisdiction permits/approvals
 - Still requires disposal of treatment media



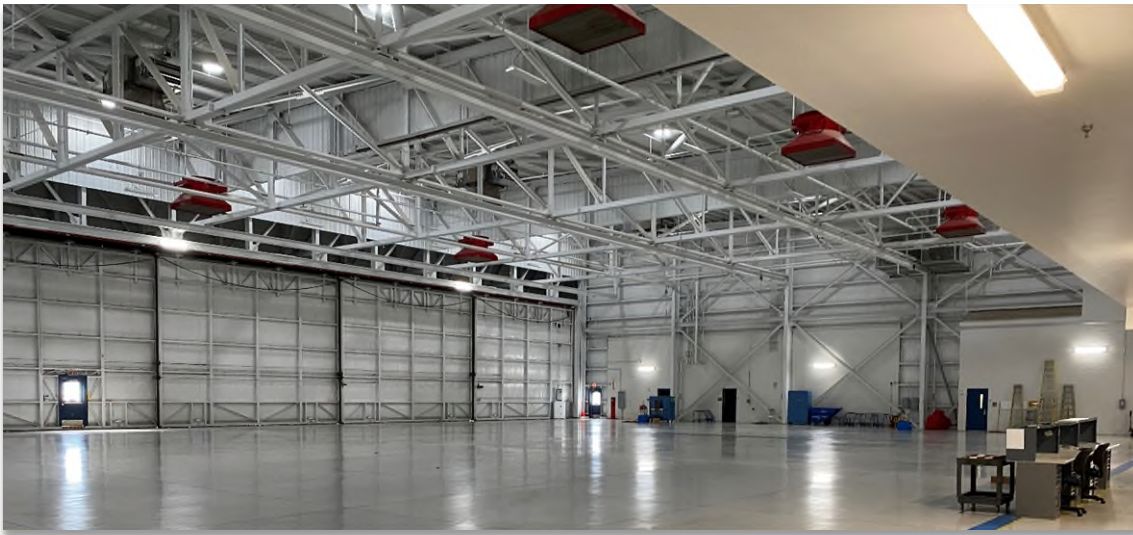
Case Study – Private Hangar AFFF Release and Conversion

- Accidental release from onsite fire suppression system
- Largely contained within hangar, exterior ramp area, and outside fire suppression room
- Portion did enter hangar trench drain and sanitary sewer system with ultimate discharge to a local river
- Emergency Response Contractor responded, contained and cleaned up release (onsite, sanitary sewer, and river) including full washdown of hangar
- Additional clean-up and investigative actions conducted of onsite and offsite soil, drinking water, surface water, sediment, and fish tissue
- Groundwater evaluation ongoing
- Led to transition of AFFF to water-based fire suppression system



Case Study - Hangar Deluge System Cleaning and Conversion

1. Remove concentrate and isolate system components in direct contact with AFFF from other system components (at/after proportioner)
2. Remove, rinse, disposal of direct contact AFFF equipment
3. Complete system modification/conversion from dry deluge to full wet system (close/open sprinkler heads)
4. Flush entire system (~3,500 LF – 7,000 gallons)
 - Main line flush – 30 minutes
 - Lateral lines – 5 to 10 minutes
 - Generated ~80,000-gallons (limited control on flow rate)
5. Discharged flush waters direct to onsite trench drain and holding tank prior to onsite treatment and discharge



Case Study – Disposal of Release and Conversion Wastes

- Waste waters treated onsite to remove PFAS
- Solids sent to landfill for disposal.
- Required development of treatment and discharge plan
- Application and approval of discharge permit by local regulatory agency
 - Agency coordination and identification of appropriate permits
 - Multiple agency departments involved = long process
- Batch treatment (20,000-gal frac tanks) and sampling
 - Concerns of cross contamination from storage tanks
 - Agency permit required non-PFAS contaminant analysis
 - pH issues - ongoing monitoring and adjustments at discharge
- Maximum discharge concentration = ND for all 36 PFAS compounds analyzed – ND \sim LOD (ranged 4-8 ppt)
 - Analysis by Modified EPA Method 537.1 by ANAB Accredited laboratory (DoD QSM V5.3)
- Onsite discharge only and in 20,000-gal per day batches
 - NO direct discharges to surface water body allowed



Challenges Associated with Onsite AFFF Treatment

- Potential High PFAS Influent Concentration
 - TOP analysis indicates Total PFAS in the PPM level
 - Precursor compounds may present persistence to treatment
- Stringent Discharge Requirements
 - Example standard - onsite discharge ND (<4 ppt)
- Required Analytical and Data Turnaround Times
 - May need to hold treated water for weeks awaiting clean data due to lab constraints
 - Freeze concerns (winter)
 - Facility disruption and space concerns
 - Cost increases due to schedule delays
- May require additional offsite treatment & disposal
 - Two or more phases of treatment increase costs and complicate transport and contracting



Case Study - Onsite PFAS Treatment AFFF Release

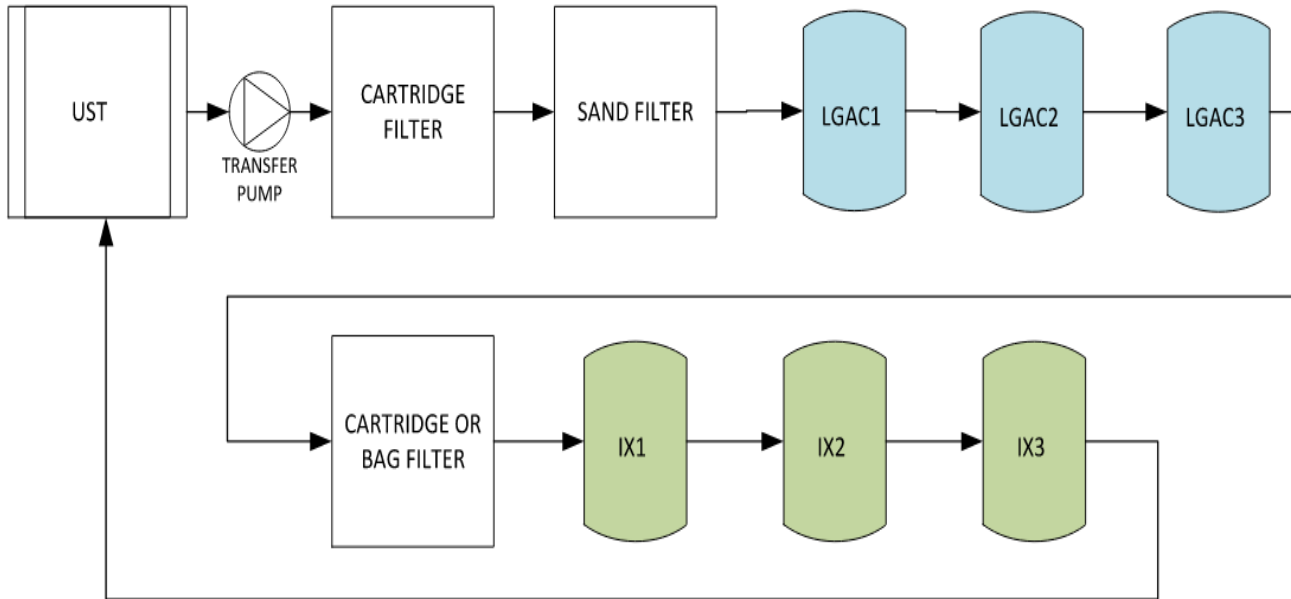
Liquid Waste:	165,000 gallons (initial release and system flush waters)
PFAS Concentration:	Total PFAS Concentration: 19 mg/L
Project Approach:	2-week pilot study Bench-scale study – suspected precursors Full-scale treatment @ 8 gpm
Treatment:	SORBIX AvPure IX
Effluent Concentration:	Discharged at Non-Detect (~4ppt) for all measured compounds
Cost Savings	> 50% vs. Offsite Incineration
Waste Footprint Reduction	> 99%



Note: Case Study Treatment Design & Operations Provided by ECT2

Case Study - Step 1 - Pilot Study

Basis: GAC/Sorbix IX Treatment Scheme



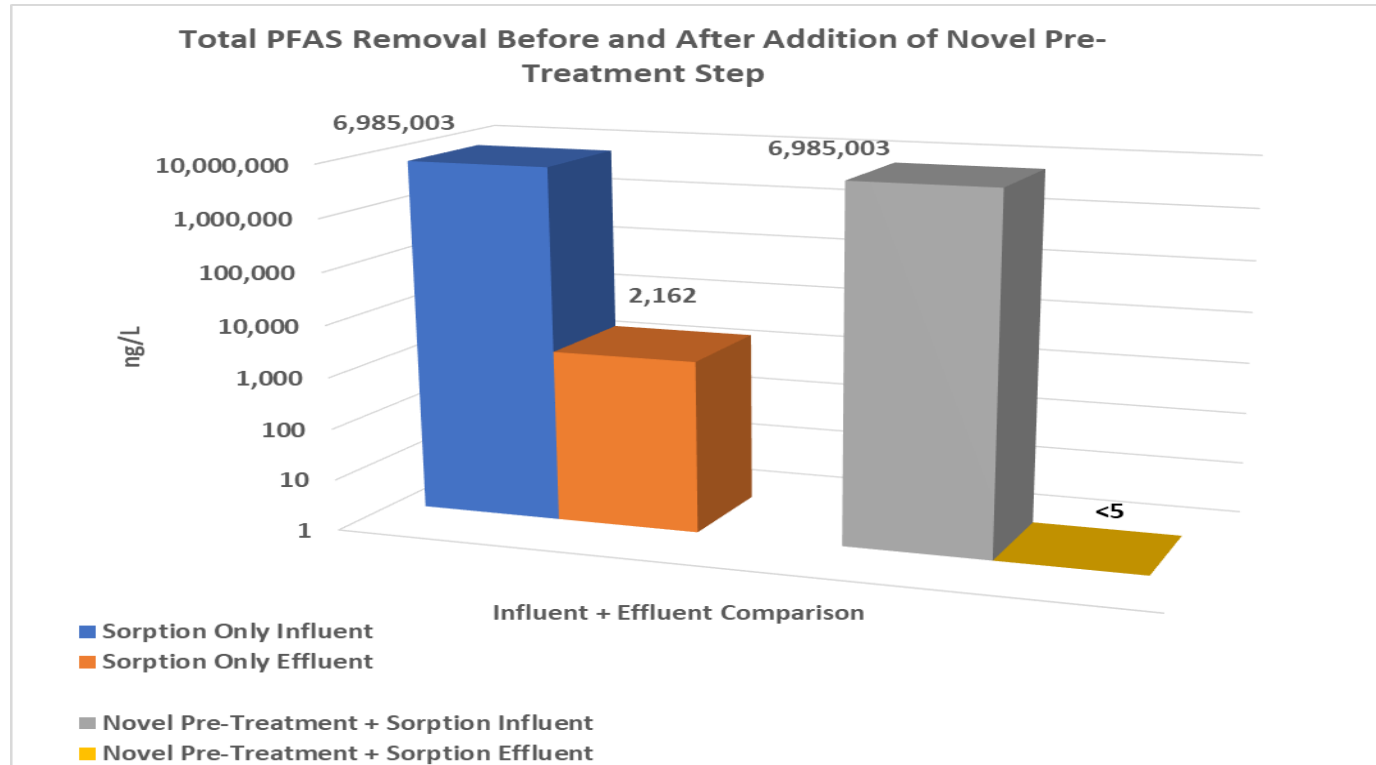
Issue 1: Influent concentration much higher than expected
Issue 2: PFOS concentrations still present after GAC and IX



Note: Case Study Treatment Design & Operations Provided by ECT2

Case Study - Step 2 – Benchtop Study

Novel “AVPURE” Process Added to Treatment Scheme



Lab Testing

TOP assay confirmed the presence of precursors

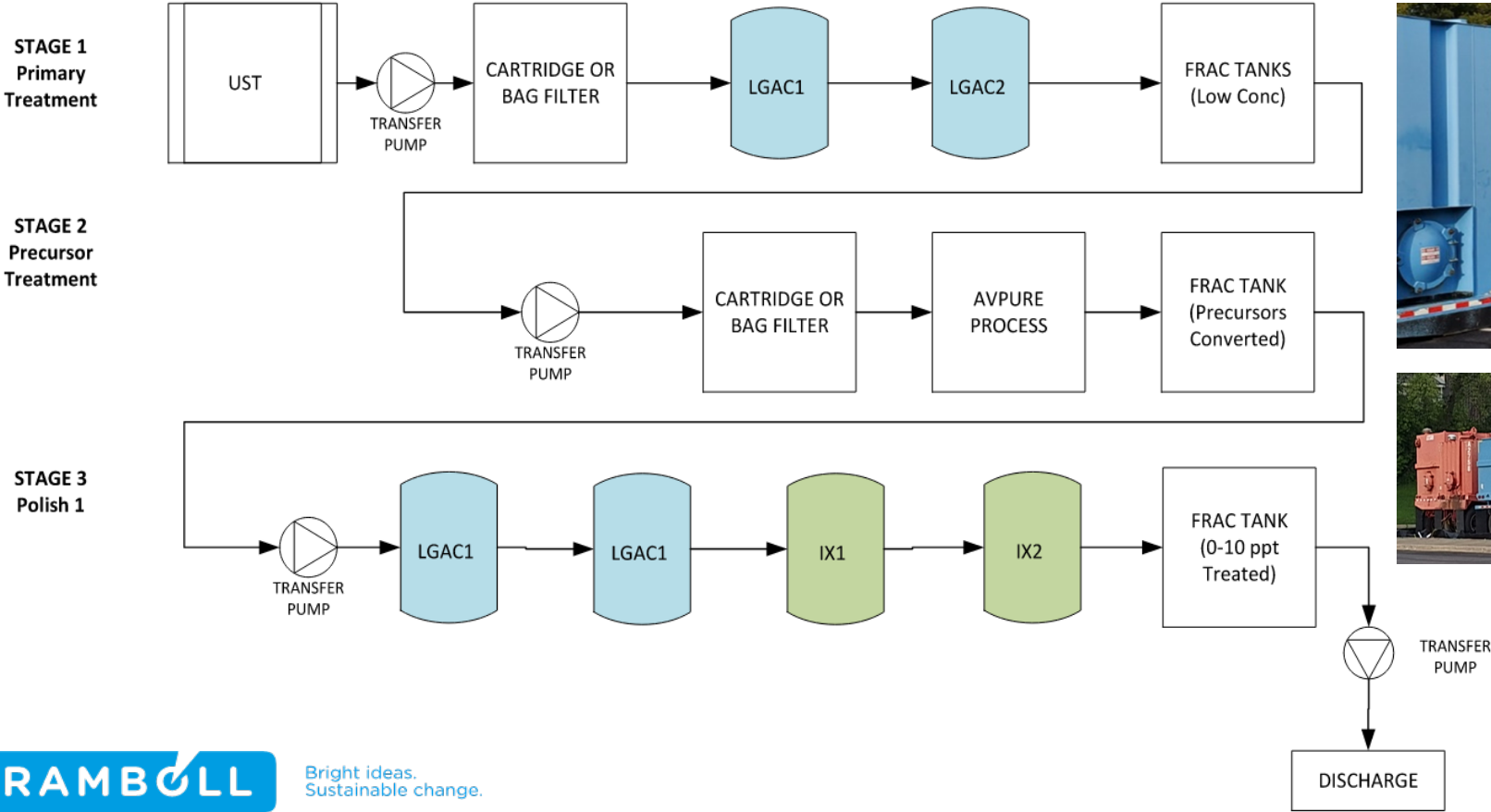
Treatment train modified to include novel AVPURE process.....



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Case Study - Step 3 - Full-Scale Treatment

Basis: GAC/AVPURE/Sorbix IX Treatment Scheme



Note: Case Study Treatment Design & Operations Provided by ECT2

Case Study - Onsite PFAS Treatment AFFF Release - Results

Quantity Treated:	165,000 gallons
Price per gallon treated (at the time) :	< \$3.00 / gallon
Cost Savings:	> 50% vs. offsite incineration

Takeaways:

- Precursors can show up as PFOS in effluent but can be converted to terminal PFAS compounds and treated effectively
- Quickly able to startup and develop overall novel treatment solution (using AVPURE proprietary process)
- Onsite treatment was cost-effective – not always the case for foam concentrate or low volumes of liquid – need cost benefit analysis of disposal options



Note: Case Study Treatment Design & Operations Provided by ECT2

Cost-Benefit Analysis – Onsite vs Offsite Treatment & Disposal

Example – Fixed Incineration vs 40 gpm Mobile PFAS Treatment System Used for Long Term PFAS Treatment

Item	Option A Off-Site Incineration	Option B On-Site Treatment
IDW Coordination Labor per Drum ^A	\$170	\$170
Off-Site Incineration Cost per Drum	\$1,500	\$0
Water Quality Characterization for Design	\$0	\$5,000
Waste Characterization for Incineration/Disposal per Drum ^B	\$180	NA
Assumed Quantity of Drums for Incineration/Treatment	100	100
Gallons of PFAS-Impacted Liquids for Incineration/Treatment	5,000	5,000
Treatment System Capital Cost ^C	\$0	\$275,000
Treatment System Flow Rate (gpm)	NA	40
Freight, Startup Labor	NA	\$20,000
Total Construction Cost	\$185,000	\$312,000
Treatment Duration (hours)	NA	125
Treatment Days	NA	15.6
Treatment O&M Labor Cost ^D	NA	\$2,400
Effluent Sampling Costs ^E	NA	\$4,320
Media Replacement ^F	NA	\$16,000
Replacement of Pumps, etc. @ Year 10	NA	\$25,000
Media Disposal Cost ^G	NA	\$3,750
Annual Operation Costs	\$0	\$26,470
1st Year Total Costs	\$185,000	\$338,470
Annual Cost After 1st Year	\$185,000	\$26,470
Annual Price per Gallon Year 1	\$37.00	\$67.69
Annual Price per Gallon Year 2	\$38.11	\$5.29

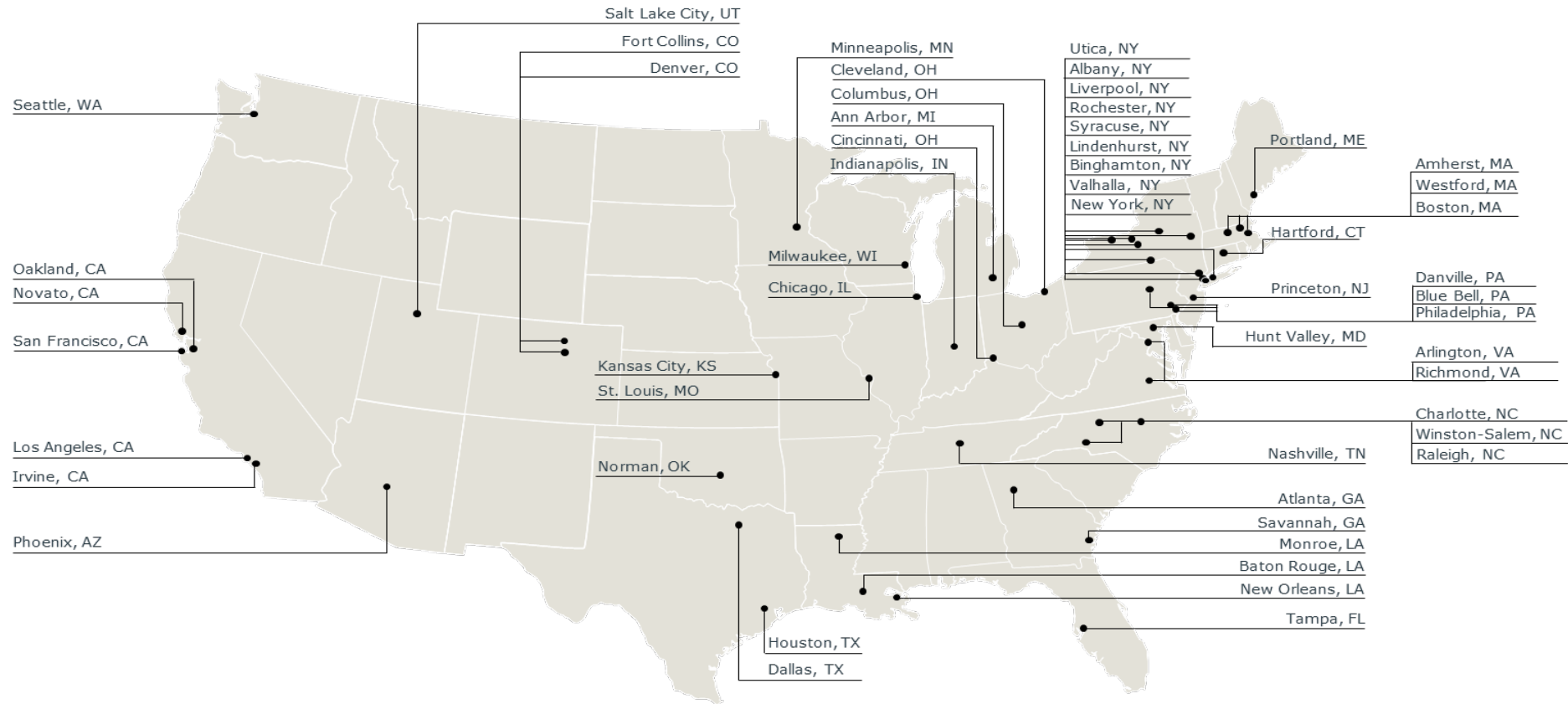
20-Year Cumulative Cost		
Year	Option A	Option B
1	\$185,000	\$338,470
2	\$375,550	\$365,734
3	\$566,100	\$392,998
4	\$756,650	\$420,262
5	\$947,200	\$447,526
6	\$1,137,750	\$474,791
7	\$1,328,300	\$502,055
8	\$1,518,850	\$529,319
9	\$1,709,400	\$556,583
10	\$1,899,950	\$583,847
11	\$2,090,500	\$611,111
12	\$2,281,050	\$638,375
13	\$2,471,600	\$665,639
14	\$2,662,150	\$692,903
15	\$2,852,700	\$720,167
16	\$3,043,250	\$747,432
17	\$3,233,800	\$774,696
18	\$3,424,350	\$801,960
19	\$3,614,900	\$829,224
20	\$3,805,450	\$856,488



Breakeven in Year 2 based on 100 drums per year

77% lower cost for long term onsite treatment





Thank you!



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Extra Slides

PFAS-Containing AFFF Conversion Approach

Ramboll strives to develop an actionable, site-specific strategy to remove PFAS-containing Aqueous Film Forming Foam (AFFF) from fixed fire-fighting systems and apparatus that aims to:

1. Meet client objectives and regulatory requirements,
2. Limit disruption to business operations,
3. Be efficient and cost effective, and
4. Reduce future environmental impacts and liabilities.

AFFF Fire System Conversions

- Conversions are a multi-step process
- Driven by various factors:
 - External factors include regulations (state and federal), environmental liability concerns, insurance carrier requirements, and/or health and safety.
 - Internal factors include business disruption and costs
- Clear understanding of client needs and desired outcome is paramount during the initial planning stages.
- Not all clients, sites, or systems are the same.
- Success is measured on reaching clear and defined goals set during the planning stages.