ADVANCED FIRE SUPPRESSION TEST CELL (AFSTC)

A Full-scale Agent Evaluation and Logistics Platform for Halon 1301 Replacement

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Abstract
The United States Air Force has utilized Halon 1301 as a standard "total-flooding''tire suppressant for nearly 20 years. Considered an eminent threat to the Earth's UV protective ozone layer, The Montreal Protocol and The Clean Air Act of 1990 have since mandated the phaseout of halon 1301 as of 1 January 1994. As a consequence, all non-essential USAF facilities are required to implement new techniques for total-flooding fire suppression. Currently, there exists limited in-house capability within the Air Force to conduct highly automated, full-scale evaluations for normally occupied spaces such as command and control, computer room, and general use commercial installations. The newly fabricated Advanced Fire Suppression Test Cell (AFSTC) however, now provides the long-term flexibility and life-cycle endurance for sustained full-scale agent evaluation and distribution analysis. The AFSTC concept is anticipated to provide critical data on the complete spectrum of advanced total-flood agents, ultimately producing a cost effective, environmentally sensitive replacement(s) for halon 1301. The AFSTC can be best described as an "intelligent" facility capable of evaluating 1301 replacements using state of the art distribution mechanisms, control automation, and clean air combustion technology. The objective of the AFSTC project is to coordinate the logistics and full-scale development of occupationally and environmentally suitable 1301 replacements in an effort to maximize systems efficiency while minimizing installation retrofit costs,

Introduction
The continued proliferation of new and diverse tire suppression strategies in the wake of halon phaseout has overwhelmingly demonstrated the requirement for industry standard platforms to validate full-scale halon replacement candidates within "real-time" environments. The primary function of the AFSTC will therefore be to evaluate halon replacement candidates for active fire suppression efficiency, systems reliability, and live tire response under the myriad of simulated fire events that are possible occurrences within Air Force facilities and installations. The AFSTC maintains a secondary focus of validating laboratory interpretations of full-scale decomposition byproduct analysis in addition to passive fire protection research. AFSTC test evaluations will initially subject SNAP approved candidates to a baseline analysis derived from and compared to halon 1301 results within the AFSTC facility using industry standard Class B hydrocarbon fuel tires and test protocols. Down-select candidates, or those candidates demonstrating acceptable performance, will be subjected to field representative scenarios conducted within the application parameters deemed appropriate by the USAF. Originally designed as a commercial space simulator, the AFSTC mission will now maintain the flexibility to baseline and evaluate the full-range of normally occupied and unoccupied ground base and airborne total flooding applications as identified in Figure 1 (following page).

- **Mobile and Fixed Command and Control Platforms**
- **Flight Simulators**
- **Munitions and Repair Hangars**
- **Computer Centers & Data Banks**
- **High Priority Commercial Spaces**
- **Airborne Cargo Bays**

Figure 1

Background

The considerable variety of existing test platforms throughout the halon replacement community has too often resulted in test results as diverse as the agents and distribution mechanisms tested within them. The attrition and interpolation of data compiled among the several test fixtures presented an alternative, yet was equally cumbersome, susceptible to error, and further costly. The newly constructed AFSTC facility was therefore implemented to uniformly validate and test potential halon 1301 ***replacements*** and ***alternatives*** under real-time Air Force scenarios. Replacement candidates are typically characterized as being those agents that can readily "drop-in" to existing halon 1301 distribution systems with little or no retrofit. This grouping of first generation, commercially available agents as well as the developmental second generation exotics are principally dominated by the halocarbons. Alternative candidates have also surfaced as viable replacements for an increasing number of total flooding applications, often pairing existing technologies and innovative engineering concepts into potent fire protection systems. The AFSTC is anticipated to provide a median of transition from laboratory scale agent evaluation to the user community. Implementing both a laboratory setting and stringent test protocol, the AFSTC is intended to maintain an exceptional level of repeatability and confidence all within a full-scale environment. Figure 2 below identifies several of the USAF uniaue characteristics and capabilities of the AFSTC.

- **Full-scale total flood platform**
- **Real-time fire evaluation**
- **Agent Evaluation**
- **Distribution mechanics**
- **Passive tire mechanics**
- **Toxicity and decomposition by-product analysis**
- **Technology transfer**

Figure 2

AFSTC Full-scale Total Flood Platform

The AFSTC consists of three major areas, a 3-zone test area of 6000cf, an environmental chamber of 3200cf, and a control/data acquisition area. The FSTC is capable of modeling both active and passive fire scenarios, primarily of CF_3Br installations. **All** necessary mechanics, control automation, instrumentation, and data collection required to perform fire suppression analysis, toxicity measurement, materials compatibility, and simulated storage stability are incorporated within the design of the AFSTC. Air flow and level, temperature, pressure, humidity, and other ambient sensors are also provided. This integration of a full-scale simulator and laboratory, will mirror industry and NFPA-12A and 2001 standards as well as provide data points unique to the facility. Reproducibility and consistency within such parameters will ensure industry credibility. Logic test sequencing will consist of system specific software that will completely control all preburn, bum, suppression, and re-ignition scenarios. Control automation will consist of D/A triggered relay networks that will activate and deactivate 80 channels of AFSTC hardware and equipment such as agent discharge valves, HVAC systems, fire detectors, and overpressure static grilles. Simultaneous data acquisition software will monitor and log all information collected from sensor devices calibrated for **3-D** temperature, pressure, flow, humidity, and gas chromatography. Environmental and occupational issues such as toxicity and clean air combustion will be allocated through the use of both in-line FTIR and GCMS technology. The AFSTC is further provided 6 camera and observation view ports at all three zones to document candidate performance on multiple point video.

- **6000cf 3-zone test volume**
- **Toxicity & decomposition sampling**
- **Simulated H-1301 distribution system**
- **10000cfm forced air & ventilation**
- **Ambient control & climatic flux**
- **Multi-point class A - D capable**
- **80 channel control & data acquisition**
- **Occupationally & environmentally sound**

Figure 3

The pre-engineered AFSTC is **40'-0"** in width, **38'-0"** in length, and 13'-0" at maximum height. The test area is 25'-0" **x** 20'-0" x 12'-0" in dimension consisting of deep-seated ceiling and subfloor test spaces of 18" and 30" respectively. The exterior finishes are provided **304** stainless steel panels which are readily cleanable, waterproof, and resistant to acidic corrosion. Test partitions achieve a simulated flame spread of 20, smoke generation of less than 100, and a thermal conductivity factor of less than 0.1 BTU/hr. Test cell structurals are completely doubled lined with 80mil. HDPE with inset monitoring fabric to detect and detain any potentially hazardous substrates that may result from testing and subsequent washdown processes. All AFSTC wall, ceiling, and floor panels are mobile and may be altered to simulate virtually any desired computer room or commercial space class A and C fire scenario. The subfloor raceway of the AFTSC will provide a hidden, deep-seated space with a raised, removable floor system to simulate those of a typical command and control (C & C) installation or commercial space. Such raceways represent the primary combustible zones of the facility, as they are often laden with the high voltage energizing source and the ignitable casements and conduits.

AFSTC Agent Evaluation & Distribution Mechanics

The primary agent evaluation objective of the AFSTC is to validate small and medium scale analyses regarding first and second generation halon replacements. First generation halocarbons have already undergone extensive small, medium, and full-scale testing, and are for the most part commercially available. Although not true drop-ins, these chemicals represent the closest semblance to halon **1301** in agent characteristics and distribution mechanics, thus earning the classification **as** a replacement **as** opposed to an alternative. User reluctance to incorporate these systems however, has been spurred by the weight, space, and retrofit costs associated with an inferior replacement. Toxicity issues related to COF, and HF agent decompositions have also hindered acceptance. The USAF policy regarding first generation halocarbon replacements basically reflects that of industry, which is to implement the halon banking system and wait for the "better than halon" second generation replacement. In light of ever changing regulatory changes, first generation testing must continue if the requirement for halon 1301 replacement accelerates before the second generation "silver bullet" can be identified.

- **Candidate Replacements**
  - **Commercially available 1st generation halocarbons**
    - HFC-227ea
    - HFC-23
    - FC-3-1-10
    - HCFC Blend A
  - **Exotic 2nd generation fluoroiodocarbons**
    - Five digit halons (13001)
- **Candidate Alternatives**
  - **PAA misting technologies**
    - Single fluid
    - Dual fluid atomization
  - **Encapsulated Micron Aerosol Agents (EMAA)**
    - Solid pyrotechnically generated aerosols
    - Hand held/fixed modular
  - **Inertblends**

Figure **4**

The second generation fluoroiodocarbon CF_3I, has demonstrated the capability to perform equally as well **as** halon 1301 in both suppression efficiency and inertion, while safely maintaining a toxicity level several times its extinguishing concentration. Yet similar to first generation replacement candidates, CF_3I maintains unique characteristics to be accounted for. The density of CF_3I for instance is significantly greater than CF_3Br, potentially resulting in AFSTC distribution modifications to optimize performance and to minimize retrofit costs should this candidate be selected.

PAA misting technologies have principally been dominated by micron size water distribution using either single or dual fluid atomization. Single fluid distribution relies on substantially high water pressures of between 200-2000psi to generate a fine mist of water particles. Single fluid misting has demonstrated to function most effectively at a single orifice flow rate of 1.0-2.0gpm generating droplets at 80-120 microns. Dual fluid water misting, or those systems using a pressurized gas to shear the water particle well beyond its natural surface tension, has demonstrated an enhanced tire suppression capability at flow rates of 0.5-1.0gpm and greatly reduced water pressures of between 30-50psi. Although both systems have successfully extinguished **Class A,** B, and D fuel fires, the dual fluid technique generates a significantly finer particle, behaving similar to a gaseous agent. Coupled with an inert atomizer such as CO_2 and N_2, tire suppression efficiency is enhanced even further. The greatly reduced quantities of water relative to sprinkler systems, has validated the use of watermist for an expanded number of total flooding applications, including the sensitive electronic and computer room spaces that the AFSTC is intended to simulate.

Encapsulated Micron Aerosol Agents (EMAA) for AFSTC evaluation consists of solid pyrotechnically generated tablets of 0.5-1.0kg that will be ignited in two of three oven generators for total flood analysis. A parallel-track "aerosol grenade" technique will also be employed as a hand-held, hand-thrown canister for stand off or hidden space fire suppression. The AFSTC will provide a typical scenario of a subfloor raceway fire to evaluate the possibility of accessing a floor panel(s) and discharging the EMAA canister as an immediate response ensemble for the installation user, either as a stand-alone or supplement to a delayed total flood discharge. Although aerosol extinguishment efficiency is several times more potent per equivalent mass of halon 1301, its lighter than air properties are anticipated to undergo significant design modifications during the development of the EMAA/AFSTC delivery system.

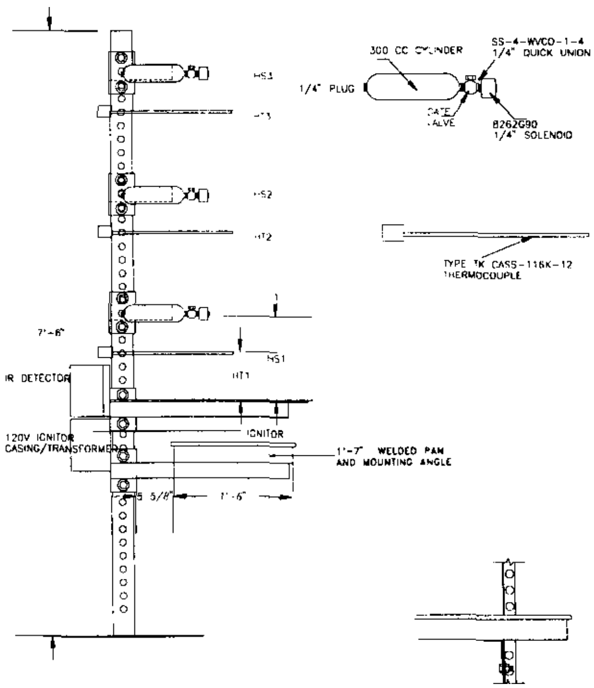

Figure 5

The typical AFSTC baselining riser as illustrated above (Figure 5), represents the typical hardware to be used to evaluate Class **B,** 99.9% N-heptane extinguishment. Four risers and **2** ambient stands will provide the ability to produce a variety of fire events at any number of six locations and elevations simultaneously. Each stand is equipped with an interchangeable array **of** sized fire pans representing small, medium, and large scale fire events all within the AFSTC. Automated ignitors, thermocouples, UV/IR detectors, and 300cc solenoid actuated vacuum collection cylinders are distributed both vertically and horizontally throughout each riser to evaluate real-time fire suppression efficiency and 3-dimensional, time elapsed decomposition by-product analysis. In-line sampling techniques are being developed to identify real-time AFSTC concentrations of O_2, CO, and CO_2, as well as decomposition by-product acids and toxins such as

HF and COF_2. Reflash screens located in the vapor combustion zone of the hydrocarbon fuel source will represent the heated and energized chassis of typical equipment following the initial suppression common to a 1301 protected space. The "holding capacity" or inerting concentration of chemically active agents (CAA) remains of paramount importance due to the lack of cooling exhibited. Down-select candidates, or those agents and distribution mechanisms successfully completing preliminary baseline evaluation, will proceed to small, intermediate, and full-scale fire testing using Class **A,** C, and limited **D** combustibles.

The AFSTC is equipped with several unique distribution systems designed to evaluate the full range of replacements and alternatives. The illustration below (Figure 6) identifies both a simulated halon 1301 distribution system as well as a single and dual fluid watermist system. The ceiling space, test area, and subfloor raceways are provided simultaneous or stand alone 1301 distribution as a means of evaluating the true drop-in capabilities for halon replacement candidates.

Distribution Mechanics

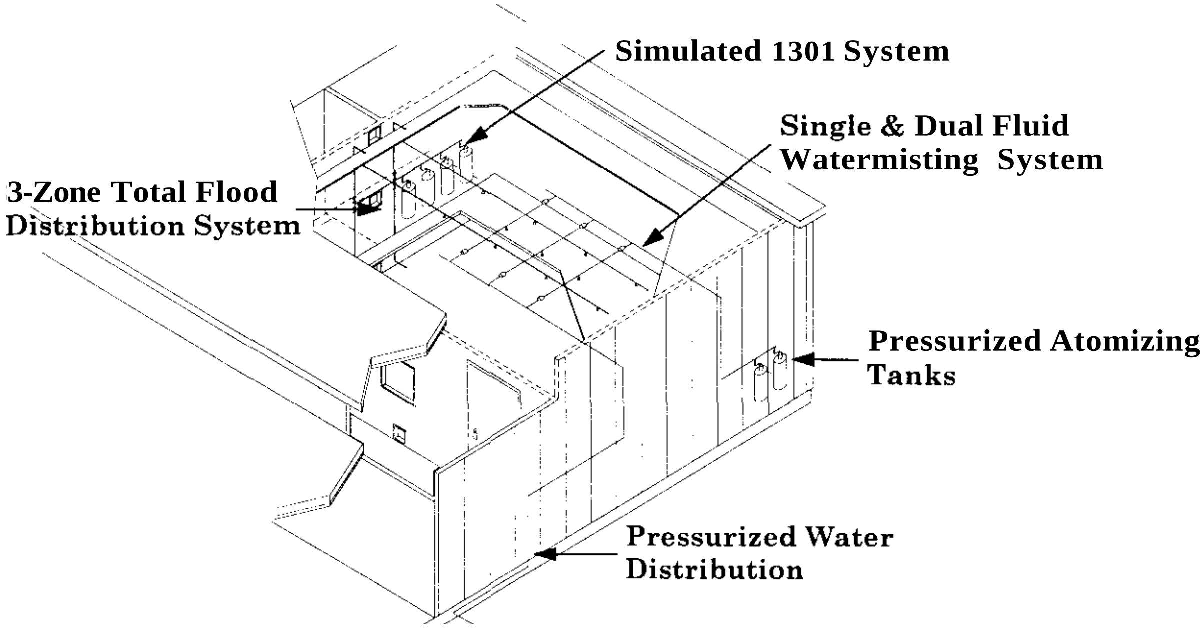

Figure *6*

Distribution systems for other suppressant technologies such as the aerosols are also incorporated. This full-scale environment will be especially challenging for halon replacement alternatives. Due to the physical properties of most candidate alternatives, rapid discharge, suppression concentration, and deep penetrating agent distribution, present significant design challenges well beyond the scope of both first and second generation halocarbons. The ability of these PAA systems to adequately suppress fires is far more dependent on distribution mechanics than that of total flooding halocarbons, especially in light of the complex geometric and deep-seated confinements of most **C** & C and commercial spaces.

Progressing outward from the primary focus of agent and distribution evaluation, new evidence and lessons of old have suggested a number of secondary active techniques that could be developed or reinstituted to enhance agent performance in a consistent, cost effective manner. As previously noted, watermisting has combined the technology of small particulate generation with the powerful thermal adsorption properties of water. As a consequence, the greatly increased surface area relative to equal volumes of water can greatly enhance the suppression capability of a commonly used technique. Such systems may prove to replace or at least supplement the use of halons in borderline applications such high priority commercial spaces where the sustainment of limited collateral damage may be preferable to the high cost and potential toxicity associated with many first generation replacements and alternatives currently being marketed. Finally, AFSTC evaluations regarding candidate agents and associated distribution mechanics will be subjected to a selections matrix similar in concept to the sample first generation replacement and alternatives chart presented in Table 1 below.

ATTRIBUTE	ATTRIBUTE WEIGHT	HALON 1301	PFC-410	HFC-23	HFC-227ea	NAF S-III	R-595	
Ext. Efficiency	4							
Vapor Pressure	4							
Boiling Point	3							
Residue	3							
ODP	5							
Atm. Lifetime	4							
Availability	3							
Cost	3							
Storage Stability	3							
Material Comp.	4							
LC50	4							
Cardiac Thresh.	4							
Conductivity	5							
Recyclable	2							
	Weighted Total							

Table 1 (Sample only)

Passive Fire Suppression Systems

A half dozen of the several proposed first generation candidates remain available for AFSTC project consideration following revised EPA and user requirements regarding ozone depletion, atmospheric lifetime, suppression efficiency and toxicity. Of those, nearly all require between 1.5-3 times the extinguishing volume of agent relative to density for acceptable fire suppression. Under the 10 second discharge limit broadly established by the NFPA, a new and significant breed of collateral damage may surface as a result of discharge overpressures resulting from 2-3 times the discharge volume within the same time constraint. As a consequence, the AFSTC is equipped with 2 static pressure louvers that will utilize an array of pressure and strain gauges to evaluate the structural response at +/- Spsi. These automated pressure dampers will also provide the capability to systematically control and fluctuate air infiltration as a surrogate method of determining the limits of a candidates extinguishing concentration. As a tertiary function, the louvers will provide emergency overpressure relief and post test ventilation.

The AFSTC is capable of automated forced air and ventilation balancing, temperature, humidity, and passive exhaust, all of which is logic sequenced into any given test scenario. The forced air system can individually or simultaneously ventilate any one of eight ceiling registers and subfloor plenum grilles to fully simulate the two primary means of air distribution in a typical USAF facility space, Although HVAC and electrical service to a space or facility zone **is** almost always deactivated during a tire event, the AFSTC maintains the ability to oxygenate a space for conservative test results and simulated systems failure,

External Technology Transfer

The AFSTC is anticipated to rapidly become the full-scale link in a chain of external small and medium scale predecessors. This approach has already fostered a wide diversity of input, scaled validation, and substantial cost savings through ongoing small and intermediate scale research. The real-time tire scenarios to be implemented within the AFSTC will provide a very close simulation of full-scale fire threat analysis, ultimately minimizing **loss** of life and collateral damage.

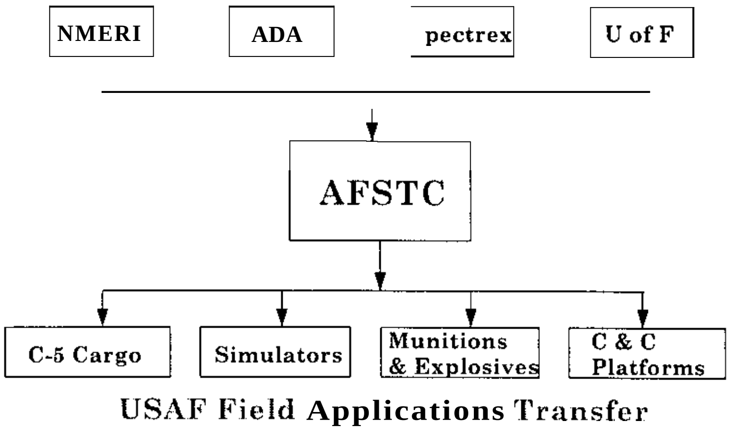

Figure **6**

The industry credible and uniform results of full-scale C & C and commercial space tire evaluation attained within the AFSTC will be transitioned to other USAF related projects **as** well **as** to other Department of Defense and commercial interests.

Objectives Summary

Halon replacement within Air Force facilities and installations worldwide has preempted much concern throughout the user community regarding the future of building fire protection and occupational safety, not to mention the enormous costs of retrofit. The prime objective of the AFSTC project will be to further coordinate the logistics and full-scale development of occupationally and environmentally sound halon replacement options in an expedient, yet comprehensive fashion. The primary beneficiaries of the AFSTC project will be the user community, who can be assured that every attempt to simulate real-time fire events will have been made to fully evaluate the true fire suppressing capability of halon **1301** replacements and alternatives as a means of thwarting the devastation and loss of life that too often results from tire and collateral damage.

AFSTC Halon 1301 Replacement Test Program

ID	Name
1	FSTC Agent Evaluation
2	EMAA/SFE Aerosol Analysis
3	Oven Generator Total Flood Analysis
4	Cargo Bay Portable Tablet Analysis
5	Hand-held Cannister/Grenade EMAA/SFE Analysis
6	1 - Generation Halocarbon Analysis
7	PFC-410 Analysis
8	FM-200 Analysis
9	R-595 Inergen Analysis
10	FE-13 Analysis
11	NAF S-III Analysis
12	2 - Generation Halocarbon Analysis
13	CF3I & C3F7I Modular TF and Streaming Analysis
14	Misting Technology Analysis
15	Watermisting Analysis
16	C6F14 Misting Analysis
17	FSTC-SF Agent Analysis
18	FSTC-SF Climate Controlled Agent Analysis
19	FSTC-SF CC Post FSTC Exposure Analysis
20	
21	
22	

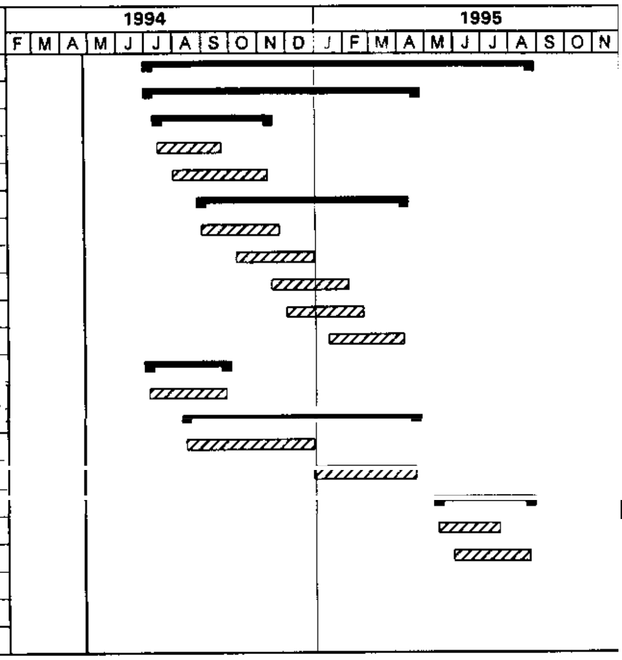

Table 2

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