# Development of Perfluorocarbons As Clean Extinguishing Agents

## SYSTEM AND FIRE TEST PROTOCOLS

by

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## Development of Perfluorocarbons as Clean Extinguishing Agents: System and Fire Test Protocols (Total Flooding and Streaming applications)

### Introduction:

The programs to develop acceptable replacement clean extinguishing agents (CEA's) for the halon agents are being completed at this time. Due to the Montreal Protocol directives, the halons will no longer be produced after December 31, 1993. New CEA's will begin to be used in new and existing systems as users seek to find safe and effective protection for their sensitive and high value hazards.

The process of developing a new CEA may take as long as five years with agent chemical development, extensive toxicity testing, environmental evaluations, fire extinguishing evaluations, code writing, and development of standards for testing new agents and systems. This process has cost millions of dollars for each new agent individually, and collectively has contributed a significant portion of the effort to replace ozone depleting chlorofluorocarbons (CFC's) and halons.

This paper will review one aspect of developing a new CEA, that of agent and system fire performance and mechanical component testing and the protocols that are being used by various agencies. The paper will focus on the perfluorocarbon CEA's, PFC-410 (perfluorobutane) and PFC-614 (perfluorohexane), in total flooding and streaming agent test protocols, respectively. The Underwriters Laboratories (U.L.) standard U.L. 1058 modifications and USAF and USN military flightline fire testing scenarios will also be described.

### General:

### U. L. 1058 Standard:

The most widely accepted standard for testing and evaluating clean extinguishing agent systems is the U.L. 1058 standard, originally developed for Halon 1301. U.L. 1058 is now being modified for use in evaluating new CEA systems. This standard covers component evaluations, systems performance testing, and fire extinguishment. As this standard was developed for Halon 1301, which had a long history of satisfactory performance in the field, it was considered prudent to take a conservative approach in evaluating the new CEA systems and **use** certain modifications in U.L. 1058 to compensate for the uncertainties about new agent performance.

When **U.L.** undertakes to list a new CEA the general information required is summarized as follows:

Agent Composition. (1)
Agent Physical Properties. (1)
Agent Vapor Pressure and Filling Density Data. (1)
Material Safety Data Sheet (MSDS) & Product Toxicity Summary Sheet (PTSS). (1)
Compatibility Data (Metals Corrosion) (1) and (2)
Manufacturing Specifications (with H20 content) (1)
Fire Test Data. (2)
EPA Approval of the Agent as a Halon Replacement. **(3)**
System Component Descriptions. (4)

This information and more is gathered from (1) the agent manufacturer, (2) the U.L. test program, (3) the EPA, and (4) the equipment supplier. When the system hardware has not been U.L. listed previously, the full compliment of tests as described in U.L. 1058 must be done.

When, as is the case most often seen, the system hardware has already been listed by U.L., the hardware testing can be greatly simplified and abbreviated. Only the tests used to evaluate the interaction between the agent and the system components need be done. These tests of agent and component interaction are those most modified for new CEA system evaluations and these modifications will be detailed later in this paper.

## Military Flightline Fire Testing Scenarios:

The U.S. Military is the worlds largest user of Halon 1211 for flightline fire fighting activities. The activities involve the use of handheld, portable fire extinguishers; wheeled, portable fire extinguishers, and crash fire rescue vehicle (CFRV) mounted systems. The typical charge of Halon 1211 in these extinguishing systems is 20 Ibs., 150 Ibs., and 500 Ibs. respectively. Over the years of working with Halon 1211 on flightlines, the military (USAF and USN) has developed several fire training and testing scenarios to evaluate agent, system, and personnel performance. The scenarios closely match the fires typically encountered on flightlines and are scaled to the capabilities of the extinguishers listed above.

In general, the handheld extinguishers are limited to small (<75ft.$^2$) spill/pool fires, engine fires and small three dimensional running fuel fires. Larger (to 800 ft.$^2$) spills/pools can be handled with the wheeled extinguishers and larger fires (full crash) are handled by the CFRV's which carry aqueous film forming foam (AFFF) in addition to the Halon 1211.

In the evaluation of new CEA's as replacements for Halon 1211, the military flightline fire training and testing scenarios have remained largely the same, but the specified protocols have been modified to more closely represent actual field conditions and to give a basis for comparison to the current Halon 1211 capabilities. The actual fire test protocols and some typical fire performance data using 3M brand clean extinguishing agent, PFC-614, will be described later in this paper.

## Test Highlights:

### U.L. 1058

The modifications, made by the U.L. engineers to U.L. 1058, were made in order to re-establish the confidence levels for the new CEA's that were previously enjoyed with Halon 1301. The particular tests needed for the evaluation of a new agent in previously U.L. listed hardware, the comparison to Halon 1301 protocols, if different from **CEA's,** and the reasoning for the modifications, when applicable, are highlighted in the following table:

| Test | U.L. 1058 Reference Paragraph | Evaluation Criteria Protocols | Halon 1301 Pass/Fail Criteria | CEA Pass/Fail Criteria | Reasoning for Modification |
|---|---|---|---|---|---|
| Discharge Test | 21 | • Min. nozzle pressure<br>* Max. discharge time<br>• Max. pipe length | As determined<br>< 10 Sec.<br>As determined | | |
| 30-Day Elevated Temp. | 24 | • 30 days at 130°F (max. storage temp.) | < 4%/yr. weight change | Same | ---- |
| One Year Leakage Test | 30 | • One year at 70°F<br>• 4 samples of each valve sue<br>• Provisional approval | < 4%/yr. weight change<br>1,2, 6, 12 Mo. checks<br>* 90 days | Same<br>* One year | * No provisional listing based on short term test (new agent) |
| Mounting Device | 31 | * 5 times weight of full charge<br>* Largest cylinder & valve (non-floor supported) | No movement | Same | ---- |
| Liquid Level Indicators | 45A | • Calibration of indicators at 40°F to 130°F<br>• Tallest vessel for each diameter | Plotted for design manual | Same | ---- |
| Gasket and 0-Rings | 46.1C | • 30 days at 70°F & 300 PSIG<br>* Largest O-rings and gaskets (12) | > 60% of orig. tensile strength and elongation | Same | ---- |
| High Pressure Discharge | 35 | • Discharge at man temp. & pressure<br>• One cylinder | Do distortion | Same | ---- |
| Area Coverage Flammable Liquid Fire Testing ("Ma. Agent Throw") | 32 | • Max piping length<br>* Min. nozzle pressure<br>* 3" heptane tires in comers<br>* baffled area with 3" high enclosure<br>• 30 sec. prebum | < 60 sec. ext.<br>< 60 sec. ext.<br>Listing to 30" high | < 30 sec. ext.<br>< 30 sec. ext<br>Must test or height | Faster ext. for new CEA's to compensate for lack of field experience |
| Fire Exting. Tests<br>1. Class "B" | ---- | * 10x10'x12' room<br>* 30 sec. prebum<br>* 18"x18" pan | < 60 sec. ext. | < 30 sec. ext. heptane, acetone, toluene | Lack of experience with new agents - Class "B" tire performance history needed |
| 2. Height of Enclosure | ---- | * 10'x10'x listing height | Listed to 30' high - automatic with coverage tests | < 30 sec ext. heptane | Varying agent densities must be tested |
| 3. Class "A" [Surface) | ---- | * 1/2"A" crib<br>* 5# excellsror<br>* 5# shredded paper | No longer done | Done for new CEA's | Class "A" fire performance history needed |
| 4. Class "A" (Deep Seated) | ---- | * Undefined | None listed | None listed | Done for occupancy tests only |

The above table **is** based on information gained from **U.L.** during the "preliminary investigation" of Fike Pre-Engineered Systems and PFC-410 Clean Extinguishing Agent. The "preliminary investigation" work is expected to lead to a Fike System **U.L.** listing and a PFC-410 component recognition by June of this year. As can be seen from the above table, only seven (7) agent/equipment interaction areas need be tested and five (5) fire performance areas investigated when a new CEA is used with previously **U.L.** listed hardware. The changes *to* the pass/fail criteria in the areas of extinguishing time, provisional listings on the one-year leakage test, Class "B" flammables tested, Class "A" fire tests and "height of the enclosure" fire Performance verification have largely been instituted because of the uncertainties and lack of a positive history now seen with the new halon replacement agents. As the confidence levels for the new agents increase, some of the fire performance criteria may be relaxed for future **U.L.** listing investigations and possible provisional listed may be granted before the full one year leakage test is completed.

## Military Flightline Scenarios

The fire scenarios developed for training and evaluation of systems and agents for military flightline use simulate very closely actual fire emergency situations. These scenarios have been developed and refined over the past several years when Halon 1211 was the primary clean agent used. In recent years the **USAF** at the New Mexico Engineering Institute (NMERI) and the Tyndall AFB, plus the **USN** at Beaufort MCAS have used these scenarios to compare the performance of new CEA candidates with Halon 1211.

The general types of training fires used in these evaluations are classified as "pan", "engine nacelle", "3D running fuel" and "pit". The pan fire scenario **is** meant *to* simulate small, spill and pooled, liquid fuel fires on the flightline. These small fires, up *to* approximately 75 $ft.^2$, are fought using handheld portables, while larger pans, up to 400 $ft.^2$, may use a wheeled extinguisher. Engine nacelle fire scenarios use 55 gallon drums, welded together *to* form a baffled, engine nacelle mockup. These scenarios simulate the possible fires in and around the engine and are normally handled with a hand-portable extinguisher. The three dimensional (3D), running fuel scenario couples a running fuel spill from a nacelle mockup into a pan. This scenario closely simulates a broken fuel line in an engine spilling fuel onto the flightline surface. This more challenging fire can be fought with either a hand-held portable or a wheeled extinguisher. The pit fire is *to* simulate a large spill/pooled, liquid fuel fires around a "hot refueling" operation. These fires can be as large as 800-2000 $ft^2$, and are handled with a wheeled extinguisher. Fires larger than those that can be handled with a wheeled extinguisher are covered by CFRV tactics using foam as the primary extinguishant and dry chemical or Halon 1211 for the 3D portions of the fire.

In the above fire training and evaluation scenarios, there are variations in the specific ways the tests are run that are unique to each testing location. These variations can be in test set-up, fuel, fuel depth, preburn time, and surface (concrete for dry weather or water layer for wet weather) of the test area. Extinguishers are normally 20# hand held type and 150# wheeled type which are standards for military flightline use. The individual differences in testing protocols among USAFINMERI, USAF/Tyndall and USN/Beaufort are shown on the following table.

| Fire Type | USAF/NMERI | USAF Tyndall | USN/Beaufort |
|---|---|---|---|
| Pan (Spill) | * Variable size<br>• Steel rings (114" thick)<br>* Water layer | * Concrete (open spill) | • Steel rectangle wlbaffles<br>• 6'x12' (1/2" thick) |
| Engine/Nacelle | | | * 2 sets of 2@ 55 gal. drums welded w/baffles |
| 3D/Running Spill with Nacelle | * 2@ 55 gal. drums welded together wlbaffles<br>• Spill from Nacelle into pan | * Same as NMERI | • 2@ 55 gallon drums<br>• 6'x12' pan<br>• Gravity spill from Nacelle mock-up onto inclined metal slide |
| Pit | • Concrete Bermed area<br>• Water layer | • Earthen bermed area<br>* Water layer | • Concrete bermed area<br>• Water layer |
| Test Variables | | | |
| Fuel | JP-4, JP-5 | JP-8 | JP-5 |
| Fuel Depth | 114" | 1/8" - 114" | 1/4" - 1" |
| Prebum Time | 30 - 60 sec. | 15 - 30 sec. | 30 sec. |
| Fuel Flow Rate | 1 -3 GPM (Pumped) | 1 GPM (Pumped) | Gravity spill - approx. 1/2 GPM |

| Location | Test Type | Agent | (Sec.) | (Sec.) [illegible] | Agent Flow Rate (lbm./Sec.) |
|---|---|---|---|---|---|
| | | | 30 | | |
| USAF/NMERI | • 150ft$^2$ | PFC-614 | | | --- |
| | • 3D/75ft$^2$ pan (3 gpm rate) | PFC-614 | | | ---- |
| USAF/Tyndall | * 3D/75ft$^2$ pan | PFC-614 | | | *9.7* |
| | • 3D/75ft$^2$ pan | Halon 1211 | | | 8.4 |
| | • 250 ft$^2$ concrete | PFC-614 | | 6.0 | 6.3 |
| | * 250 ft$^2$ concrete | Halon 121 1 | | 6.0 | 5.0 |
| USN/Beaufort | • Pan (72 ft$^2$) | PFC-614 | 30 | 7.2 | 1.3 |
| | * Nacelle | PFC-614 | 30 | 25 | 1.6 |
| | * 3 D/pan | PFC-614 | 30 | 16.1 | 1.2 |
| | • Pit (810 ft$^2$) | PFC-614 | 30 | 22.9 | 4.8 |

The above tests were run under controlled conditions and the results are typical. The relative performance of PFC-614 vs. Halon 1211 can be characterized as comparable, but not equivalent. Quantitative comparisons vary depending on the type of fire scenario used and the preburn times involved. The PFC-614 is delivered as a more liquid stream, therefore, its cooling abilities and throw range are typically superior to Halon 1211. The chemical extinguishing mechanism of Halon 1211, on the other hand is superior to the largely cooling mechanism of PFC-614. With these characteristics of the two agents coming into play, PFC-614 has improved performance when hot metals that lead to reflash are involved (nacelle and 3D fires) and Halon 1211 has superior performance when large pool fires are involved (Pan and Pit).

It must also be pointed out that the use of hand-held equipment to extinguish fires for any CEA (PFC-614 or Halon 1211) is extremely operator dependent. The training of the fire fighter not only is key to the optimum use of the agent and maximum personnel safety, but is essential for instilling and maintaining the high confidence levels in these CEA's needed to successfully attack actual "fires-in-anger".

**Summary**

From the preceding pages, it becomes obvious that a great deal of development work is involved in preparing a new CEA as a replacement for the halon agents currently in use. The fire performance and system testing are just one aspect of any development program and the protocols for this test work are under constant and thoughtful review in order to develop meaningful criteria by which to judge the new agents.

When the NFPA required testing of a total flooding agent is completed by U.L., or similar testing organization, the end user is assured that the listed CEA system has been evaluated under a strict set of conditions common to all CEA's. The user can then make an informed and safe choice as to which system is best for any given hazard. Listing tests also serve as a method to verify the given NFPA 2001 extinguishing concentration requirements for flammable liquids and the extinguishing concentrations for Class "A' combustibles as well. These extinguishing concentrations are the basis of "design" and "use" concentrations calculated in the final system design.

The test comparisons used by the military in flightline fire scenarios also give the required evaluation of candidate CEA's while maintaining a "level-playing field" on which all CEA's can be compared. These tests also are necessary to the total agent development in giving a quantitative measure of how well a new agent will replace the existing halon in flightline systems.