CLEAN AGENT SYSTEMS TESTING USING A SUSTAINABLE HALON REPLACEMENT ALTERNATIVE TO HFCS

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ABSTRACT
Since the legislative demise of Halon 1301, a variety of clean agent fire suppression alternatives have surfaced over the past decade. While some have been successful in ensuring life safety, property protection and continuity of operation, the search for the "perfect" halon substitute has eluded the industry. Several in-kind and not-in-kind agents have been widely accepted for use in total flooding applications through traditional listings and EPA SNAP (Significant New Alternatives Policy) approval programs.

Developed over the past 5 years, FK-5-1-12 is a relatively new and patented fluoroketone clean extinguishing agent technology commercially known as 3M™ Novec™ 1230 Fire Protection Fluid. FK-5-1-12 has been demonstrated to be very versatile in standard system application. Stored and transported as a liquid but expelled as a gas from N_2 pressurized cylinders, the effectiveness of FK-5-1-12 has been successfully demonstrated in accordance with the requirements of UL2166 in third party listing and/or approvals testing with Underwriter's Laboratories (UL), Underwriter's Laboratories of Canada (ULC) and FM Global Enterprise (FM). It complies with virtually all-major global regulatory approvals and is EPA SNAP approved as safe for use in occupied spaces.

Novec 1230 Fluid is included in the latest editions of NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems and the ISO 14520 Standard on Gaseous Media Fire Extinguishing Systems.

Results from recent witnessed flow testing will be discussed. Further, two-phase flow capabilities will be discussed, the validation of which has led to a listed and approved pre-engineered and engineered system. This presentation will also identify the unique properties of handling FK-5-1-12 that allow its use with novel application methods.

INTRODUCTION
Determination of a clean agent's flooding utility requires attestation of a system's ability to deliver the agent into a protected space or spaces under prescribed conditions with defined parameters governing the system operation. A number of recognized models are available that use as a basis Bernoulli's Theorem and the assumption of a quasi-steady state flow of a two-phase fluid. TSP Ansul's clean agent system using FK-5-1-12, commercially known as Sapphire™, has completed that validation testing. Using one of those models and benchmark testing against the criteria outlined in UL Standard for Safety for Halocarbon Clean Agent

Extinguishing System Units, UL2166[i], has enabled for the first time the use of a truly sustainable halocarbon technology in traditional hardware common in the industry using unbalanced system design techniques.

TESTING

NITROGEN ABSORPTION

Two-phase flow validation requires assurance that a test cylinder containing FK-5-1-12 is completely saturated with superpressurizing nitrogen gas. A simple test was conducted to determine if agent would absorb nitrogen while in a static state. A cylinder was filled with agent with the head space pressurized to 25 bar (360psig). The cylinder was allowed to stand for 3 days, and it maintained a constant pressure during that period. Upon one rotation of the cylinder, the pressure dropped approximately 10% indicating that, without significant contact of the nitrogen with the agent, accomplished by some method of agitation, complete equilibration of a cylinder with a can only occur over a very considerable period of time.

This test resulted in a procedure of pressurizing the test cylinder with nitrogen with mechanical agitation to allow the agent to absorb nitrogen. The most efficient method determined was to roll the cylinder. Pressure was added and the cylinder again rotated until the pressure stabilized. This would typically take four cycles to stabilize to the desired superpressurization. To expedite this task, a hydraulically driven table for rotating cylinders was utilitized.

Cylinders that were pressurized through the discharge port required less effort in getting nitrogen to absorb. This forced the nitrogen from the base of the pickup tube to the top of the cylinder, thus increasing the amount of contact between nitrogen and agent.

FK-5-1-12 COLLECTION

Another requirement for the two-phase validation is exact confirmation of the amount of agent flow from a given nozzle. In the past, this was accomplished by measuring volumetric concentrations of agent in air in various enclosures , which differed in size into which a system nozzle would discharge agent. Then, agent concentration was measured by use of calibrated three-point chart recorders or more sophisticated Fourier Transform Infrared (FTIR) analysis. For system testing using FK-5-1-12, however, the unique liquid character of the agent allowed for its discharge from a nozzle and collection in plastic drums with gasket sealed covers. Attached to the drums were large balloons that captured the nitrogen and any agent that converted to gas. Nozzles were placed inside the containers with PVC cups placed over the nozzles. This minimized the conversion from a liquid to a gas and allowed a place for instrumentation to be attached. Full port valves were placed outside the container on the discharge piping. After discharge, the valves were closed isolating the containers from the rest of the system. All containers and balloons were weighed. This method accounted for more than 94% collection of agent and nitrogen.

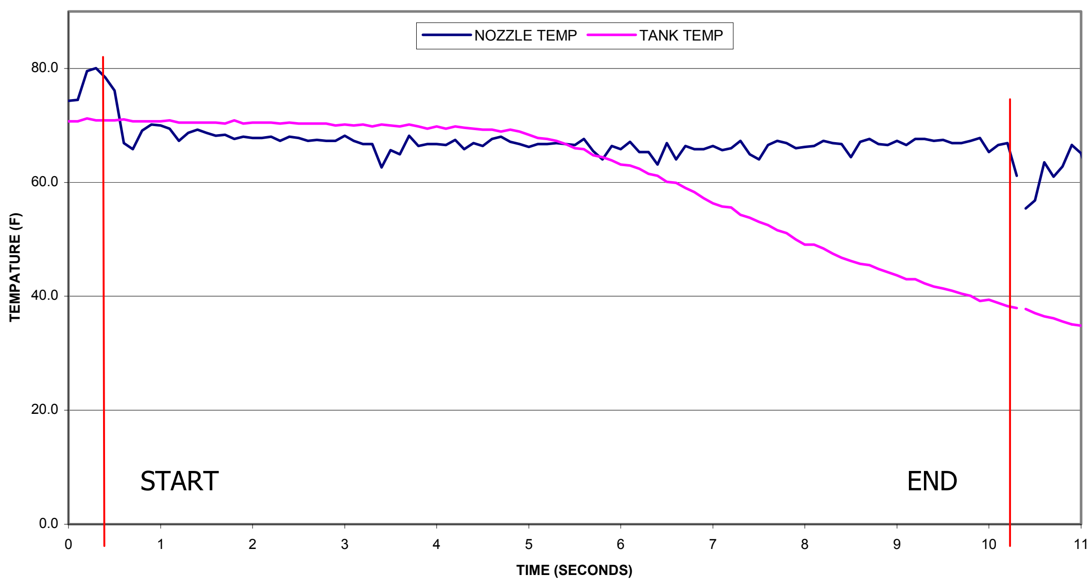
PRE-ENGINEERED - FLOW

Initial system testing using FK-5-1-12 validated a system’s performance in a balanced arrangement using one or two nozzles in a system of piping attached to a single cylinder containing nitrogen superpressurized FK-5-1-12. Prior to testing, the tank volume was measured.

A pressure transducer (PT) was located on the cylinder to measure inside tank head pressure. Also, one PT was located after the flexible discharge hose, and also one at the nozzle. One thermocouple (TC) each was placed on the tank to measure inside tank conditions and at the nozzle directly in the flow. The thermocouple at the nozzle was used to determine the start and end of discharge.

As air in the pipe was compressed, there was an initial temperature increase. When agent reached the nozzle, which defined the start of system discharge, a quasi-steady state flow was then established. The temperature at the nozzle dropped slightly but remained more or less steady during the course of discharge. The end of discharge was defined at the point when flow changed from mostly agent to mostly excess nitrogen exiting the nozzle. This is noted as a visible by a decline in nozzle temperature. See Figure 1.

Figure 1



Discharged agent creates static electricity. This prevents the data acquisition system from capturing data unless the system is grounded. Electrical grounding the pipe system and all thermocouples eliminated this concern.

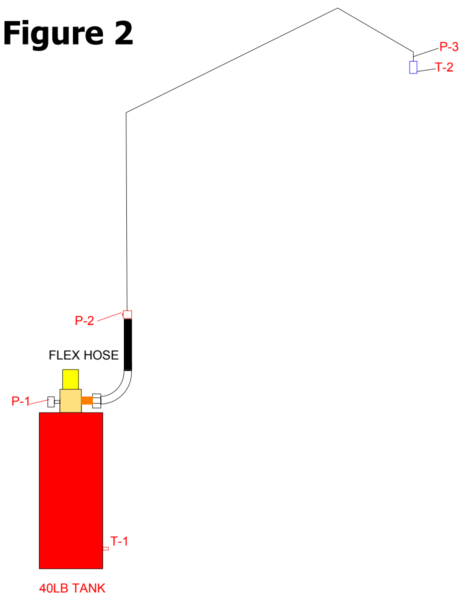
Approvals testing conducted previously established an average nozzle pressure of 71psi(4.9 bar) for a standard nozzle. The average nozzle pressure was calculated between the start and end of discharge.

Pre-testing and approval testing were conducted to UL Standard for Safety for Halocarbon Clean Agent Extinguishing System Units, UL2166.

Two limits were critical in gaining approval of a pre-engineered system. The first is a discharge time of less than or equal to 10 seconds. The second is the average nozzle pressure must be greater than or equal to 71psi(4.9 bar)

Pre-testing established a pipe system that met the maximum system limitations for the 40 and 80lb cylinders. Figure 2 depicts these pipe systems.

Figure 2



ENGINEERED –FLOW TESTING

To design the engineered software program for calculating unbalanced systems, certain data must be obtained and benchmark limits defined to result in a useful working program. Below is a list of established testing guidelines .

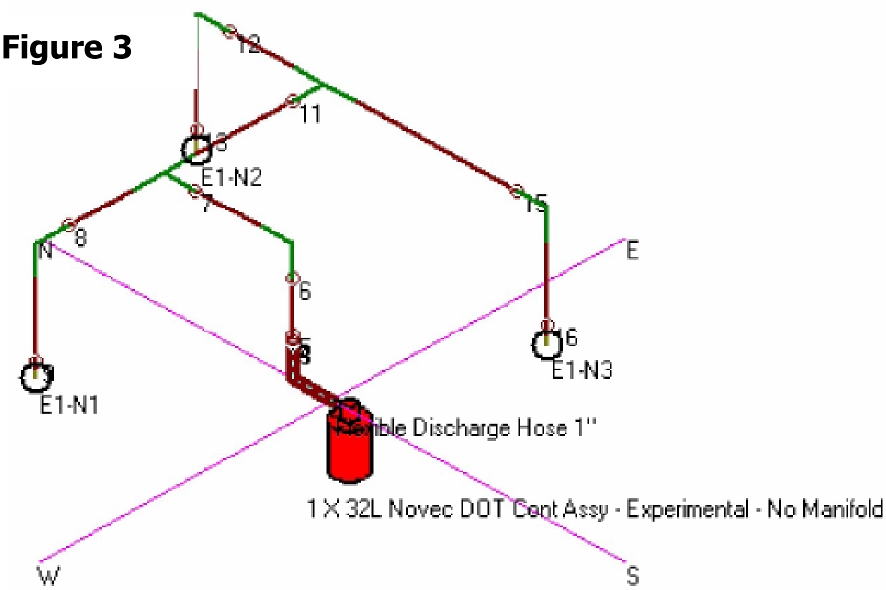
1. Prior to testing:
    - Measure and document the volume of each test cylinder.
    - Calibrate instrumentation.
2. Pressure and temperature measurements are to be taken at the following locations:
    - Cylinder head space
    - After the cylinder valve assembly
    - After the flex hose, if it exists
    - Before each tee
    - A thermocouple shall be located at each nozzle, with the tip just outside an orifice.
    - For instrumentation being placed after or before fittings being measured, the instrumentation shall be installed at least ten pipe diameters downstream.
    - Data needs to be taken at a sample rate of 0.1 seconds.
3. Pipe schematic:
    - The "as-built" drawing will include actual pipe lengths and diameters as well as any fittings that are to be used.

- Pipe lengths shall be measured from the center of the first fitting to the center of the second.

4. Before each test:
   - Properly saturate the nitrogen into the agent to the desired superpressurized cylinder pressure
   - Create a pipe schematic.
   - Determine the nozzle orifice area by pinning with a pin set (preferred) of with calipers.
   - Electrically ground the piping system to eliminate noise in the data.
   - Label the drums used to capture agent.
5. After each test:
   - Check nozzles for debris.
6. Miscellaneous:
   - Use schedule 40 pipe with 300 lb Class fittings.
   - Always reduce pipe diameters after the tee, never before.
   - Always use bushings to reduce pipe size.
   - Document anything unusual that occurs before, during or after testing which could affect the test results.

A detailed consolidated report was created for each system to be set up. It included drawings of the pipe system and all of the necessary cylinder information. Detailed information was given on the pipe size, pipe length, hardware, cylinder size, agent weight, starting pressure, and fill density. Figure 3 shows a typical piping schematic.

Figure 3



Pre-testing was conducted at TSP Ansul Inc. for initial system evaluation and analysis and to validate the robust character of the data collection methods. Data were then compiled into a software program labeled "Sapphire Designer Software."

Upon in-house verification of the software program, five pipe systems at the required maximum system limitations were built and tested for the approving authorities in accordance with UL 2166. From these five systems, two were witnessed. An additional five system designs were created by the approving authorities to be calculated with flow tests conducted to verify the accuracy of the software program.

UL2166 establishes three main criteria for approval of the two-phase flow program. They are

- Predict the discharge time within ±1 second
- Predict nozzle pressure within ±10%
- Predict mass of agent discharged from a nozzle to within ±10%.

TEST RESULTS PRE-ENGINEERED – FLOW

UL and FM witnessed one 40lb and 80lb cylinder discharge at maximum system limitations. Chart 1 summarizes data collected and system limitations.

Chart 1

Cylinder (lb)	Pipe Size (in)	Max. Pipe Length (ft)	Max. Elevation (ft)	Max. Elbows	Max. Agent Fill (lb)	Nozzle	Discharge Time (s)	Average Nozzle Pressure (psi)
40	1	45.8	14[1]	3[2]	42.5[3]	16 Port - .125" Orifice	9.7	79.3
80	1.25	36.2	14[1]	3[2]	80.4[4]	16 Port - .185" Orifice	9.4	74.3

[1] Measured from bottom of tank to nozzle tip.
[2] Flexible discharge hose does not count towards maximum number of elbows.
[3] For simplicity, the manual only allows a maximum fill of 40lbs.
[4] For simplicity, the manual only allows a maximum fill of 80lbs.

Based on this data, approval from a recognized testing laboratory was granted.

ENGINEERED - FLOW

A total of seven discharge tests were witnessed. Each test incorporated a number of the software limitations, a summary of which is described in Chart 2. These limitations were created after compiling and analyzing the data from approximately 80 flow tests.

Chart 2

Description				Limit
Fill Density (lbs/ft3)	Maximum			74.9
	Minimum			31.0
Discharge Time (sec)	Maximum			10.0
	Minimum			6.0
Maximum Arrival Imbalance (sec)				1.0
Maximum Runout Imbalance (sec)				2.0
Maximum Pipe Volume to Cylinder Liquid Volume Ratio (%)				80
Minimum Pipe Volume Ratio before First Tee (%)				10
Nozzle Area Ratio (%)	360°	Maximum		80
		Minimum	Standard	20
			15 mm	10
	180°	Maximum		80
		Minimum	Standard	20
			15 mm	10
Minimum Nozzle Pressure (psig)				73
Critical Pipe Length (pipe diameters)				10
Maximum Elevation Change (m)				4.3
Tee Splits (%)				
Bull Tee			Maximum	50:50
			Minimum	70:30
Side Tee			Maximum	90:10
			Minimum	65:35

CONCLUSIONS

Based on the flow test results compared to the software limitations approval was granted by recognized testing laboratories and validates the utility of an engineered system design for a sustainable halon replacement alternative to HFCs in that a global approval has been attained.

APPROVAL AGENCY REFERENCE NUMBERS

Underwriter's Laboratories

File: EX4510
Project: 03NK23616, 03CA05373

File: EX6263
Project: 02NK02492

Underwriter's Laboratories of Canada

File: EX4510
Project: 03CA14392

FM Global Enterprise

File: 5612
Project: 3012489, 3014138, 3014139, 3014140, 3012581

Reference

[i] UL Standard for Safety for Halocarbon Clean Agent Extinguishing System Units, UL 2166, Underwriters Laboratories, Northbrook IL, USA, 1st Edition, 31 March 1999, Revised 22 March 2001.