CONTINUING THE EXAMINATION AND COMPARISON OF EXISTING HALON ALTERNATIVES IN PREVENTING RE-IGNITION ON CONTINUOUSLY ENERGIZED FIRES

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ABSTRACT

This report continues the work performed by Smith to include the addition of two other clean agents included in NFPA 2001 and ISO 14520; HFC-236fa and HFC-125.

Objectives of previous testing were to replicate and verify that extinguishment could be achieved using design concentrations lower than the minimum cup burner levels and evaluate the effect of a constant electrical arc or ignition source above the test sample using the same extinguishing agents and design levels.

Previous results by McKenna led to the conclusion that the Conductive Heating Test protocol was unable to achieve auto ignition. As a result, the test procedure was modified to evaluate the effect of a constant electrical arc or ignition source. An electrical arc source was affixed above the cable specimens to provide continual ignition throughout the holding period. Modified Conductive Heating Tests with the arc yielded a different outcome.

INTRODUCTION

Previous guidelines given by the National Fire Protection Association (NFPA) 2001, *Standard on Clean Agent Fire Extinguishing Systems,* for the design and installation of clean agent total flooding systems are determined for either Class A or Class B fuel fires. The NFPA 2001 Standard has limited guidance for designing a system to protect Class C, energized equipment, where de-energizing the equipment is not an option. The following suggestion found in the 2004 Edition, Annex A, NFPA 2001.

> A.5.6: If electrical equipment cannot be de-energized, consideration should be given to the use of extended agent discharge, higher initial concentration, and the possibility of the formation of combustion and decomposition products. Additional testing can be needed on suppression of energized electrical equipment fires to determine these quantities.

In an effort to give guidance when designing for Class C, energized equipment, the following tests were conducted using the Modified Conductive Heating Test.

OBJECTIVE

This report presents current results from the Modified Conductive Heating Test while using extinguishing agents HFC-125 and HFC-236fa. These results on Class C energized fires should be taken into considerations when designing a total flooding system.

TEST EQUIPMENT

TESTING ENCLOSURE & DISCHARGE SYSTEM

Tests were performed in a 1.28 m^3 (45 ft^3) enclosure having dimensions 0.91m x 0.91m x 1.52 m (3 ft. x 3 ft. x 5 ft.). This enclosure was constructed with 13 mm (0.5 in.) thick polycarbonate walls held in place by a 5 cm (2 in.) angle iron frame. Two removable doors, equipped with four vise grip style compression latches, provide access to the inside of the enclosure. The doors are 29.5 cm x 29.5 cm (11.6 in. x 11.6 in.) in dimension and overlap the perimeter of the opening 3.3 cm (1.3 in.).

Two openings in the enclosure allow ventilation of the decomposition products after a test is completed. The first opening that allows makeup air into the enclosure is located 7.6 cm (3 in.) from the bottom of the enclosure in one corner whilst the second opening is located a distance of 7.6 cm (3 in.) down from the top surface of the enclosure in the opposite opposing corner. Both openings are 5 cm (2 in.) in diameter.

The ventilation system is controlled manually by activating three separate solenoid valves. The first two-solenoid valves open or close the inlet and exhaust vents. The third solenoid valve operates a Dayton Shaded Pole Blower capable of providing 24 L/s (50 ft^3/min). This blower is installed on the inlet opening. This facilitates post-test purging of gases in the enclosure and supplements the negative exhaust system on the outlet vent.

Extinguishing agent was discharged into the enclosure through a simple pipe network constructed from 6.4 mm (0.25 in.) diameter schedule 40 pipe and fittings. The total length of the discharge system piping was roughly 85 cm (33.5 in.). A 1000 cc (0.035 ft^3) stainless steel cylinder fitted with Schrader valve and a 90^o needle valve was used to achieve the range of agent concentrations needed. The valves facilitated filling and transporting the cylinder from the fill area to the enclosure. A Worcester Controls quarter turn ball valve located 10 cm (4 in) downstream of the cylinder-initiated discharge of agent. The nozzle used in the enclosure was a Bete 0 degree NF2000 nozzle. The discharge system was not optimized for any specific agent but was designed to accommodate both of the agents tested.

In order to prevent the extinguishing agent from directly impinging on the test specimens, a polycarbonate baffle system, 6.4 mm (0.25 in.) thick, was constructed and placed in the middle of the floor in the test enclosure. Low-density calcium silicate board was placed on top and bottom of the baffles. Details of this setup can be seen in the following figure.

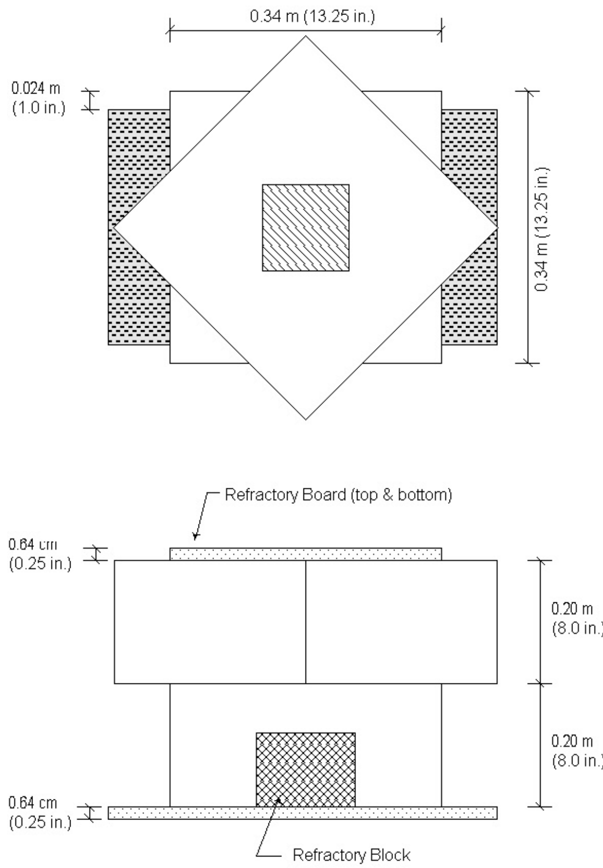

Figure 1: Details of Baffle in Enclosure

DATA ACQUISITION EQUIPMENT

Internal cylinder pressure along with discharge pressures and temperatures were recorded with a computer controlled analog-to-digital converter. The computer system is a 1500MHz Pentium based IBM ThinkPad T40 computer system running LabView data collection program. A parallel port cable is used as an interface to control an Omega OMB-Daqbook 100 analog-to-digital converter. A three slot expansion chassis containing two DBK-19 thermocouple input boards and a DBK 13 digital input board were daisy chained to the Daqbook 100.

Thermocouples were used to measure the temperatures developed inside of the test enclosure and on the top surface of the cable and wires during the tests. Starting 10 cm (4 in.) from the top of the test enclosure and spaced 30.5 cm (12 in.) apart were four 3.2 mm (0.13 in.) diameter stainless steel, exposed tip thermocouple probes. The orientation of the probes was such to form a thermocouple tree in the centerline of the enclosure. A similar 3.2 mm (0.13 in.) diameter stainless steel, exposed tip thermocouple probe was used to measure the temperature on the surface of the cable during the Conductive Heating Tests.

Three types of pressure transducers were used to measure the cylinder and discharge pressures during the test series. An Omega pressure transducer, model number PX102-500SV (0-500 psis range) was used for tests utilizing discharge pressures of 2482 kPA (360 psi) and 1379 kPA (200 psi). For all tests using a discharge pressure of 690 kPA (100 psi), two different pressure transducers were installed. The first one, model number PX242-250G5V (0-250 psis) was installed on the cylinder while the second, model number PX242-150G5V (0-150 psis) was installed near the nozzle.

TEST METHODOLOGY & PROCEDURE

This series of tests were conducted according to the protocol for vertical tests developed by HAI and is intended to demonstrate an event where current continues to flow through a loose connection. In order to accomplish this, heat is conducted directly to bare conductors of 350 mcm cable, typical of supplying large amounts of power.

Two separate cable types manufactured by Lucent Technologies were tested; type KS-5482L28FR and type KS 20921L2. The heat was provided by a Watlow "K-Ring" heater, model SKR2210201A, capable of providing 1,000 Watts of energy while operating on 240 VAC. The heater is equipped with integral thermocouple that is connected to a 240 VAC Watlow model 93AA-1CAO-00RG 1/8 DIN temperature ramping controller. This was used to replicate and control the output of the heater during the tests.

The cable was rolled off of the supply spools onto the floor for straightening. Test specimens were prepared by cutting smaller segments to a length of 260 mm (10.25 in.) and removing 108 mm (4.25 in.) of insulation from one end; exposing the bare copper conductors. The remainder of the test procedure is as follows.

The required amount of extinguishing agent was determined using the following equation.

$$m = \rho V \left(\frac{C}{100 - C} \right) \quad \text{where,}$$

m = amount of agent [kg]
ρ = vapor density [HFC-125 for 5.06 kg/m^3 at 21 ^{o}C]
V = open volume of the test enclosure [1.28m^3]
C = desired concentration [%]

- The cylinder was filled with the appropriate amount of agent in order to reach the desired extinguishing concentration and pressurized to the desired pressure with nitrogen. Next it was placed in its holding bracket on the test enclosure and attached to the discharge piping.
- The mass of the specimen was determined prior to the test.
- The bare conductor end of the cable specimen was placed into the "K-Ring" heater. A nail was pushed into the conductors to provide a firm fit between the conductors and inner wall of the heater.
- The heater and cable specimen were placed in the bottom of the test enclosure, in a vertical position and on top of a 10 cm^3 refractory block. The top baffle was placed around the heater.
- A thermocouple was inserted into the baffles then, in turn, inserted into a small hole drilled near the top of the copper cable conductor. The calcium silicate board was placed on top of the baffle.
- The test placard was completed identifying the test details and filmed with the video recorder.
- The data acquisition system, camera and heater are activated. The controller for the heater was set to 900 ^{o}C and maintained this setting until ten minutes after discharge.
- Once sustained ignition occurred, the test enclosure was sealed and ventilation system turned off.
- The extinguishing agent was discharged one minute after sustained ignition.
- Make observations for ten minutes after discharge, turn heater off, turn on ventilation system and wait for heater to cool prior to starting setup for next test.

MODIFIED CONDUCTIVE HEATING TEST

An electrical arc source was affixed above the cable specimens in order to provide this continual ignition point throughout the entire inertion period. The inclusion of this electric arc ignition source in a modified test procedure, improves upon the previous test protocol by allowing evaluation of situations in which conductive heating of cable connections occurs in close proximity to an arc that develops between electrical equipment.

A Dongan transformer rated at 6000 V (0.02 A) provided the source for the electrical arc. In efforts to prevent fouling between arc probes and potentially losing the arc source, an arc source was developed between the conductors of the cable and a probe above the top surface of the cable.

Prior to inserting the bare conductors into the "K-Ring" heater, the centermost strand was separated and twisted perpendicular to the side of the cable while the remaining strands were inserted. One of the leads from the Dongan transformer was connected to this centermost strand; now protruding to the side. A second wire attached to the remaining transformer terminal was clipped onto a 3.2 mm (0.13 in.) steel probe positioned 4-6 mm (0.16-0.24 in.) above the top surface of the cable.

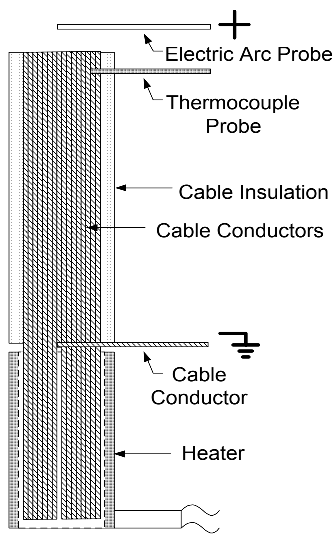

Figure 2: Test Setup for Modified Conductive Heating Test

A small hole was drilled through the cable insulation approximately 6.4 mm (0.35 in.) down from the top. The tip of the thermocouple probe was inserted into this hole so that the probe was in direct contact with the copper conductor strands.

RESULTS

After discharge of the agent, if the flame remained or diminished in intensity and remained as a small-localized flame around the arc source, then the overall result was that the fire was not extinguished (Did Not Extinguish). If the flame was extinguished and only a blue arc source was visible, the fire was deemed extinguished but the arc source remained. If the flame was extinguished and then small-localized flames were visible shortly after around the arc source, this concentration was considered to have extinguished the fire but reignition occurred. When the flame and arc source were no longer visible and remained nonexistent throughout the duration of the inertion period, this particular concentration would be considered as being capable of extinguishing and preventing reignition.

Table 1. Test Details of HFC-236fa in Selected Modified Conductive Heating Tests.

Test	Agent Tested	Cable Type	Design Concentration [%]	Reignition [Yes/No]
COND143	HFC-236fa	KS-5482L28FR	6.5	DNE
COND144			6.5	DNE
COND145			8.0	DNE
COND146			8.5	No
COND147			8.5	No
COND148			8.5	No
COND195			8.5	No
COND149	HFC-236fa	KS-20921L2	8.0	DNE
COND150			6.8	DNE
COND151			7.5	DNE
COND152			7.5	DNE
COND153			7.5	DNE
COND154			8.0	No
COND155			8.0	No
COND194			8.0	No

Table 1 indicates, HFC-236fa was successful in preventing re-ignition in two of the tests listed above, the tests using the cable with added fire resistive materials required an 8.5%, cable with out fire resistive materials required 8.0%.

Table 2. Test Details of HFC-125 in Selected Modified Conductive Heating Tests.

Test	Agent Tested	Cable Type	Design Concentration [%]	Reignition [Yes/No]
COND157	HFC-125	KS-5482L28FR	12.4	DNE
COND192			12.5	No
COND156	HFC-125	KS-20921L2	11.9	DNE
COND193			12.0	No

Table 2 indicates, HFC-125 was successful in preventing re-ignition in two of the tests listed above, the tests using the cable with added fire resistive materials required a 12.5%, cable with out fire resistive materials required 12.0%.

DISCUSSION & CONCLUSIONS

The following test results can give guidance to the fire protection design professional in design for preventing re-ignition on continuously energized fires. Table 2 indicates extinguishing concentrations established to prevent re-ignition on continuously energized fires.

Table 3. Test Details of Selected Modified Conductive Heating Tests.

Agent Tested	**Cable Type** KS-5482L28FR	**Cable Type** KS-20921L2
HFC-236fa	8.5	8.0
HFC-125	12.5	12.0
HFC-227	11.0*	11.0
FK-5-1-12	4.5	3.9

REFERENCES

1. Smith, D., Niemann, R., Bengtson, G., "Examination and Comparison of Existing Halon Alternatives and New Sustainable Agent Technology in Suppressing Continuously Energized Fires," *Proceedings*, Halon Options Technical Working Conference, Albuquerque, NM, pp.288-298, 2001.

2. Niemann, R., Bayless, H., and Craft, C., "Evaluation of Selected NFPA 2001 Agents for Suppressing Class "C" Energized Fires." *Proceedings*, Halon Options Technical Working Conference, Albuquerque, NM, pp. 399-412, 1996.

3. NFPA 2001, Standard on Clean Agent Fire Extinguishing Systems, National Fire Protection Association, 3rd Edition, Quincy, MA 2004.

4. Driscoll, M., Rivers, P., 3M, "Clean Extinguishing Agents and Continuously Energized Circuits: Recent Findings, "*Proceedings*, Halon Options Technical Working Conference, Albuquerque, NM, pp. 129-140, 1997.

5. McKenna, L.A. Jr., Gottuck, D.T., DiNenno, P.J., "Extinguishment Tests of Continuously Energized Class C Fires." *Proceedings*, Halon Options Technical Working Conference, Albuquerque, NM, pp. 12-14, 1998.