SUPPRESSION OF ELECTRICAL CABLE FIRES: DEVELOPMENT OF A STANDARD PVC CABLE FIRE TEST FOR ISO 14520-1

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INTRODUCTION

Clean fire suppression agents are currently employed for the protection of numerous assets, including electronic data processing, telecommunication, and process control facilities. Common to these facilities is the employment of electrical cables arranged in cable trays.

The current version of ISO 14520-1 (Gaseous *Fire-Extinguishing Systems, Physical Properties and System Design, Part 1: General Requirements*) requires only wood crib fire extinguishment testing for the establishment of minimum Class A design concentrations. The ISO/TC 21/SC 8 subcommittee has recognized, however, that the currently employed wood crib fire test may not indicate the extinguishing concentrations suitable for the protection of plastic fuel hazards. As a result, the ISO/TC 21/SC 8 subcommittee has appointed a special working group to develop suitable Class A test protocols, with the intent to restructure the current standard to include wood crib, polymeric sheet, and PVC cable fires. The wood crib fire test proposed for the next edition of ISO 14520-1 is identical to that described in the current standard, and the proposed polymeric sheet fire tests [1] are identical to the tests described in UL 2127 [2] and UL 2166 [3], with the exception of the employment of a larger ignition pan.

CABLE FIRE TESTS

STANDARDS

A number of national and international standards exist which measure the flammability of cables. BS 4066, Part 3:1994 [4] describes a large-scale test involving the burning of bunched cables of 3.5 meter (11.5 feet) length, oriented in the vertical position. IEEE Standard 1202-1991 [5], ASTM D-5337 [6], and UL 1658 [7] describe large-scale tests on 2.4 meter (8 feet) strands of cable mounted vertically on cable tray. On a smaller scale, BS 4066, Part1:1980 details a method for the assessment of flame propagation employing a single cable strand 675 mm (27 inch) in length and mounted in the vertical position, and UL 1581 [8] describes a test involving a single 460 mm (18 inch) long specimen mounted in the vertical position.

INDUSTRY INVESTIGATIONS

The above-referenced standards were designed to evaluate the intrinsic flammability characteristics of cable, and do not address the suppression of the fires. The suppression of cable fires in cable trays has been investigated by Sumitra [10] and by Chavez, et. al. [11]. Sumitra employed a horizontal arrangement of cables contained within twelve ladder-type cable trays stacked on top of each other, with 10.5 inch vertical spacings between trays. Vertical configurations of cable in cable tray were also investigated. The cable trays employed were 8 feet in length, 18 inches wide and 3 inches deep. Ignition of the cables was accomplished with heptane contained in an ignition pan, and the extinguishment of the fires by water was examined.

Chavez, in a study for the U.S. Nuclear Regulatory Commission, employed a horizontal configuration involving cables arranged in ladder-type cable tray, with two or five cable trays stacked on top of each other; the vertical spacing between the trays was 10.5 inches, as required by the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.75. Vertical configurations of cable in cable tray were also investigated. Ignition was accomplished employing propane burners, and suppression with Halon1301, water and carbon dioxide was examined.

The Sumitra and Chavez studies provide valuable insight into the effects of the cable type, cable loading, cable arrangement, ignition source and other variables on the characteristics of the resultant cable fire. However, the relatively large scale of the tests renders them expensive.

RECENT EFFORTS: ISO/TR 20885

Technical Report ISO/TR 20885 [1], developed by the special working group of the ISO/TC 21/SC 8 subcommittee, proposes a PVC cable fire test involving PVC cable contained in cable trays. The proposed protocol involves a specific type of cable tray and consists of six cable tray layers, each containing ten evenly spaced pieces of cable; the vertical spacing between cable trays is 20 mm (0.8 inches). Ignition is via heptane contained in a pan located below the bottom tray. At 270 seconds after ignition of the heptane, the extinguishing system is activated; the enclosure is then kept sealed for a 10 minute soak period, after which no reignition can occur.

Although data has been presented by the authors of the Technical Report that indicates the fire itself is reproducible, independent researchers have not been able to duplicate these results. In addition, the Technical Report did not examine the suppression of the proposed test fires. Researchers at Tyco Suppression Systems [12] have reported several problems associated with the proposed test method , including a lack of reproducibility of heptane preburn times, and a lack of reproducibility of the burning characteristics of the cable. Cone calorimetry testing of the cable showed no acute differences between cable lots, and the disparity in burning characteristics with the cable array were attributed to the test configuration.

The protocol proposed in the Technical Report suffers from several additional weaknesses. A specific cable tray and cable, from specific manufacturers, are specified, which could result in availability problems in different regions. The perforated cable tray specified in the Technical Report is of an unusual design, and such designs of cable tray are not available in the United

States. A survey of U.S. and European cable tray manufacturers and installers revealed that the vast majority of applications involving power cables employ ladder-type cable tray.

The stacking of cable trays on top of each other is a configuration neither encountered nor allowed in the field. None of the installers or manufacturers contacted as part of this study could recommend the stacking of cable trays, as this would not allow for maintenance of the cable system. The National Electric Code (NEC), Article 318-6(h) states that "cable trays shall be exposed and accessible…" and NEC Article 318-6(i) requires that "Sufficient space shall be provided and maintained about cable trays to permit adequate access for installing and maintaining the cables." Hence, stacking of trays would represent a violation of the National Electrical Code.

DEVELOPMENT OF A SUITABLE TEST PROTOCOL

A fire test protocol suitable for inclusion in national or international standards should provide a reproducible fire, and the suppression of the fire should also be reproducible. In addition, as much as is possible, the cost involved in conducting the tests should be maintained at a reasonable level. The scale of the test proposed in ISO/TR 20885 is such that the costs to conduct the test are not unreasonable, but the lack of reproducibility observed renders the test unacceptable. In addition, as pointed out above, the proposed configuration involving the direct stacking of cables on top of each other is likely never to be encountered in the field. The large scale tests described above are cost prohibitive, requiring large test enclosures and large amounts of cable, cable tray and suppression agent.

The requirements for a suitable PVC cable fire test were judged to include:

- Reproducibility of the fire
- Reproducibility of suppression results
- Simple operation
- Use of readily available materials
- Sufficient fire size to present a challenge to the suppression agent
- Steady burning of all layers of fuel prior to extinguishment
- A fire which continues to burn for a suitable duration in the absence of suppression

EXPERIMENTAL PROCEDURE

PVC cable fire tests were conducted in a 115 m^3 test enclosure. The test setup employed is shown schematically in Figure 1. An aluminum rack was constructed to allow stacking of cable trays with a 12 inch spacing between trays. Chalfant brand aluminum ladder-type cable tray was employed in all tests. The cable tray was 9 inches wide with either 9 inch or 12 inch rung spacings, and was 4 inches deep. Cable tray sections of 24 inches in length were cut and mounted in the support rack shown in Figure 1. The desired arrangement of cables was prepared and ignition accomplished via a heptane starter fire. Mass loss was monitored by mounting the entire apparatus on a load cell.

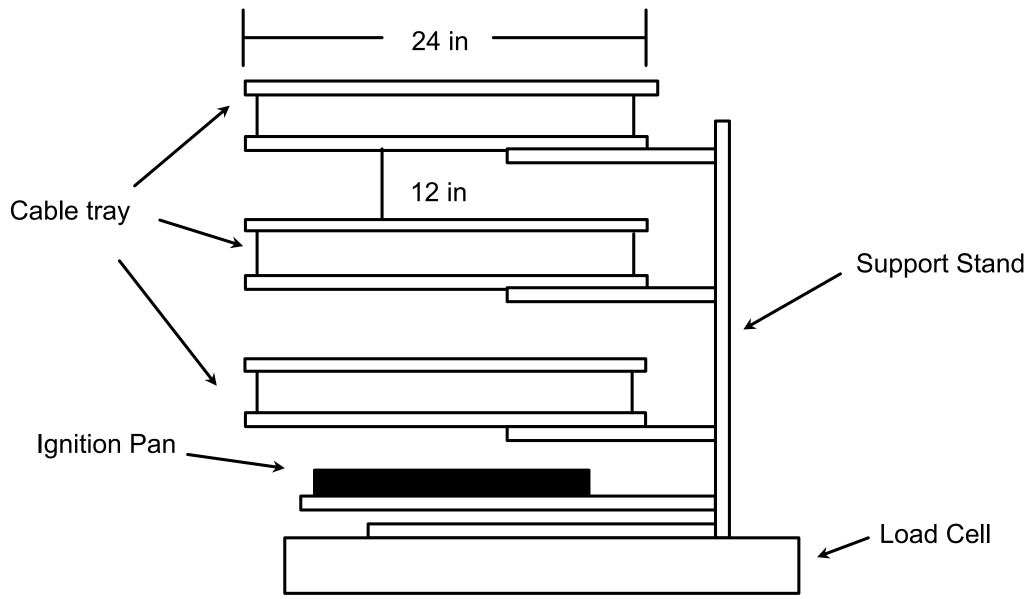

Figure 1. Test Configuration

Several types of PVC cable were examined in the course of the work, including General Cable 10/2 with ground NM-B, General Cable 12/2 with ground NM-B, Brown-West 8/2 with ground UF-B, Daniel-Walker 8/2 with ground UF-B, and Basec Doncaster (RS 368-823). The Basec Doncaster cable is the cable specified in ISO/TR 20885; the Brown-West and Daniel-Walker cable are similar in appearance and have similar fire characteristics compared to the Basec Doncaster cable (see below).

The number and arrangement of cables and cable trays was varied, as were the amount of fuel and the location of the ignition pan. Approximately fifty tests were conducted to establish a test configuration that would satisfy the requirements for a suitable standard test. An examination of the test results led to a number of general conclusions concerning the fire intensity and behavior:

1. The fire intensity depends on numerous factors, including the type of cable and cable tray employed, the cable loading and arrangement, and the duration and location of the heptane ignition fire.

2. Feedback (reradiative) effects between trays are significant and the presence of an additional tray has a significant effect on the fire characteristics.

3. Tight arrangements of cable are not as combustible as loose arrangements due to the accessibility of air to the cable surface.

4. Reduction of the distance between the ignition pan and the bottom cable tray reduces the effects of drafts on the test fires.

The conditions ultimately adopted are shown in Table 1. These conditions were felt to best satisfy the requirements listed above for a suitable protocol.

Table 1. Specification of Test Parameters for PVC Cable Fire Test

Item	Specification
Cable tray type	Ladder; Aluminum or Galvanized
Cable tray width	9 inches
Cable tray length	24 inches
Cable tray rung spacing	9 inches
Cable tray depth	4 inches
Cable characteristics	*See Table 2*
Cable length	25 inches
Cables per tray	20
Vertical spacing of trays	12 inches
Ignition pan	1/8" CS, 11 x 8.7 x 2" ; 1000 mL water, 350 ml heptane
Ignition pan lip to cable tray bottom	1.5 inches
Agent Discharge	420 seconds after heptane ignition

Table 2 summarizes the results of cone calorimetry testing (ASTM 1395) of the individual cables at a heat flux of 40 kW/m^2, and includes proposed specifications, which would allow the use of all cables indicated.

Figure 2 shows the mass loss observed during a typical freeburn. Table 3 shows the fire size at the proposed agent discharge time of 420s, and demonstrates the reproducible nature of the test fires. At 420 seconds after heptane ignition, cables in all three trays have been burning for over one minute, and a steady burning rate has been attained.

In the absence of a suppression agent, it was found that the cable fire will burn for approximately 23 minutes. It was also verified that oxygen depletion alone will not extinguish the cable tray fires; when all vents are closed at 420 seconds after heptane ignition, the fire continues to burn beyond the 10 minute "soak" period.

Figures 3 and 4 show the mass loss as a function of time for suppression of the cable tray fires with FM-200® and nitrogen, respectively, for a typical test. The cable fires were consistently extinguished at FM-200® and nitrogen concentrations of 5.8% and 30% v/v, respectively.

Table 2. Composition and Cone Calorimeter Data for Cables

Cable	External Sheath, Wt %	Internal Sheath, Wt %	Wire, Wt %	180 Second Average Heat Release Rate, kW/m^2	Effective Heat of Combustion MJ/kg	Ignition time, seconds
Brown West UF-B	34.2	12.1	53.7	149.4	17.3	24
Daniel-Walker UF-B	36.9	10.6	52.6	131.9	16.2	24
GCC NM-B	28.9	11.5	59.6	-	-	-
RS 368-823	35.9	13.4	50.7	138.2	14.4	27
Specification	34	12	54	140	15	25
Tolerance	15	10	10	10	15	10

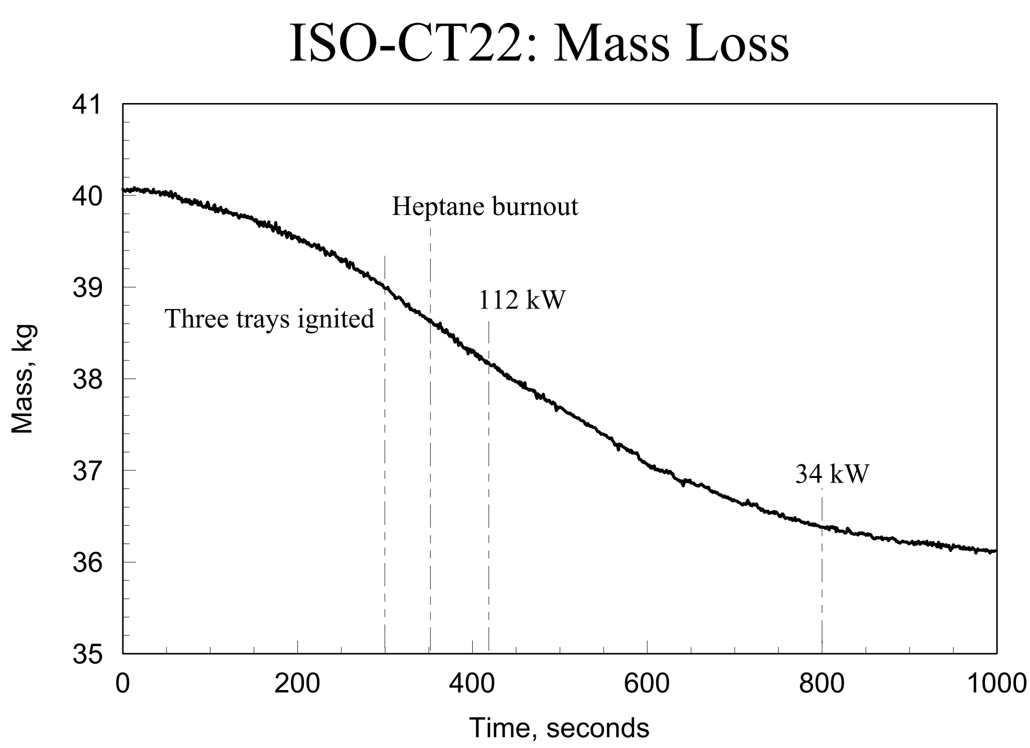

Figure 2. Mass Loss vs. Time for Cable Tray Fire

Table 3. Fire Size at Time of Agent Discharge

Test	Fire Size at 420 Seconds after Heptane ignition, kW
ISO-CT22	112
ISO-CT24	114
ISO-CT25	112
ISO-CT26	96
ISO-CT27	96
ISO-CT29	106
ISO-CT30	103
ISO-CT36	117
ISO-CT37	116

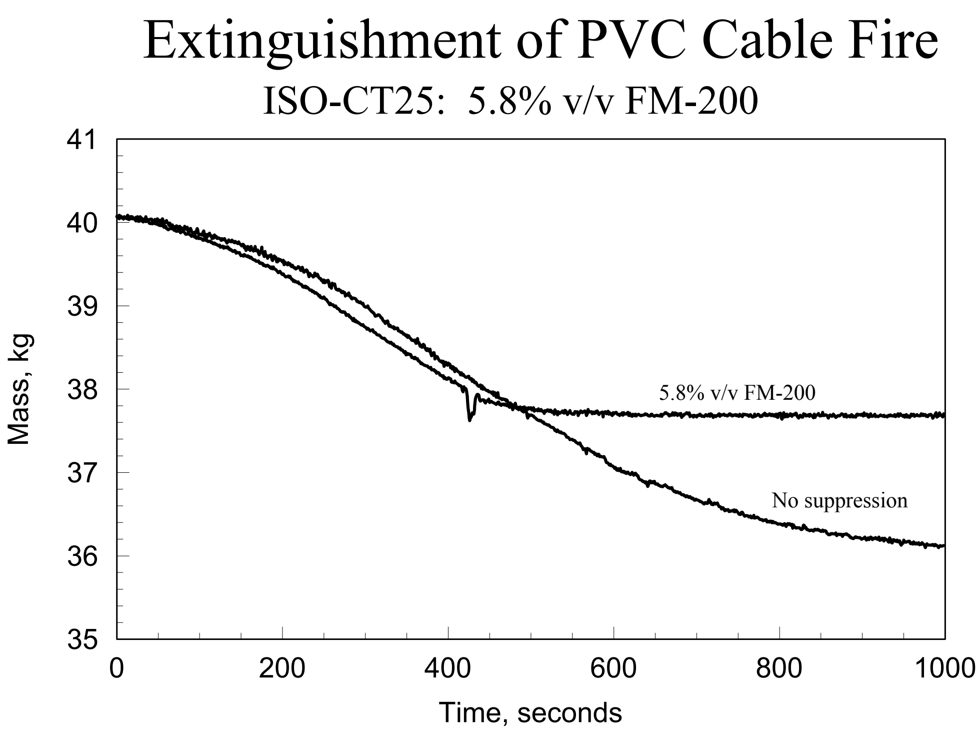

Figure 3. Extinguishment of Cable Fire with FM-200®

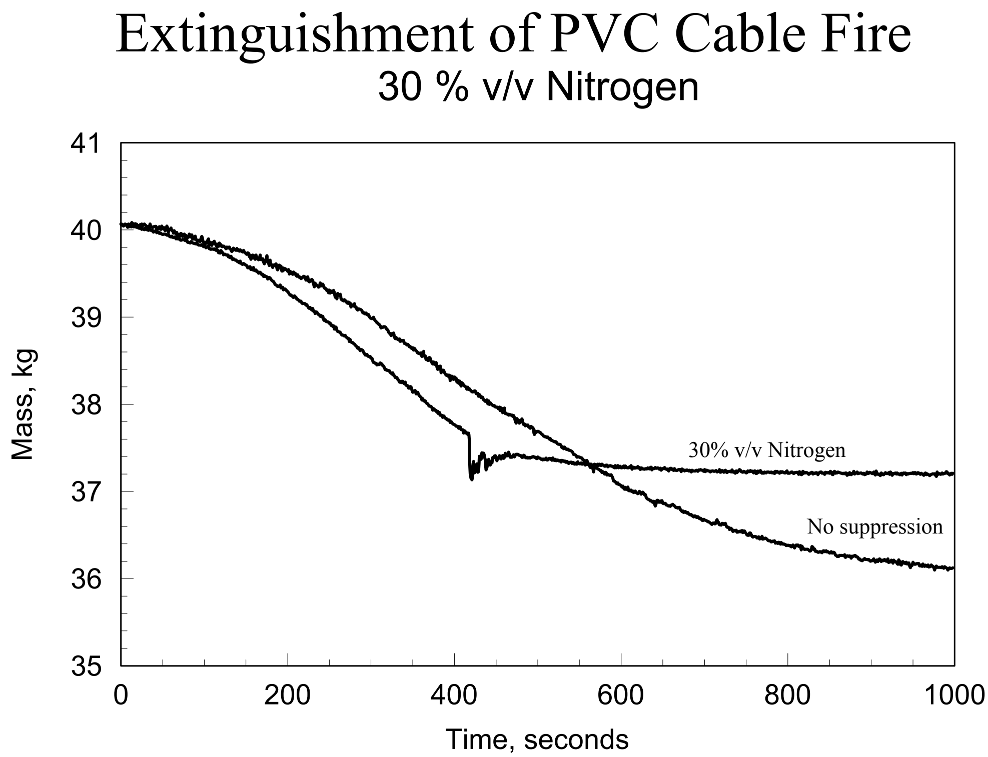

Figure 4. Extinguishment of Cable Fire with Nitrogen

CONCLUSION

A series of tests were conducted with the goal of providing information to the ISO/TC 21 SC/8 subcommittee to aid in their development of a test protocol for PVC cable fires. A set of test conditions was found which results in reproducible fires and suppression, is simple and relatively inexpensive to perform, and provides a sufficient challenge to the clean agents. The proposed test method and specifications will be submitted to the ISO committee for consideration for adoption as a standard test method for PVC cable fires.

ACKNOWLEDGEMENTS

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