PROGRESS TOWARDS THE DEVELOPMENT OF A CABLE TRAY FIRE TEST

Thomas F. Rowland, Don Couvillion, and Mark L. Robin
Great Lakes Chemical Corporation

INTRODUCTION

Test protocols were developed for PVC cable fires in ladder and ventilated trough cable trays. The protocols produce fires that are reproducible and exhibit a constant heat release rate following a heptane-induced prebum period of 90 sec. These fires produce sufficient smoke to allow for their detection well before the system activation times proposed in the protocol, and hence represent worst-case conditions.

It was observed that 5.8% FM-200® afforded rapid extinguishment of these cable tray fires, and could even afford rapid extinguishment of unrealistic cable configurations in which multiple cable tray units were stacked on top of one another. Such a stacked configuration has been recently accepted by the IS0 14520 Class **A** task group, and will be submitted to the IS0 14520 Committee for consideration for inclusion in the second edition of the ISO standard.

TEST FACILITY

The test facility is shown schematically in Figure 1. The nominal internal dimensions of the test portion of the facility are 8 x 4 x 3.6 m (height); precise measurement of the test portion of the facility yielded a total volume of 115 m^3 (4061 ft^3). The enclosure walls are constructed of standard concrete cinder block, filled with insulation, and covered on the interior with 5/8-inch gypsum wallboard. The ceiling and floor both consisted of two layers of ¾ inch plywood on wooden 2 x 6 joists, with alternate layers of plywood staggered so that no joints overlap. The ceiling is also covered with 5/8-inch gypsum wallboard, and the walls and ceiling have been finished with tape and joint compound and painted with two coats of primer (Kilz). The windows consist of standard units employing safety glass and are covered on the interior with Lexan sheets. The enclosure door is of standard solid core construction.

A 1 x 1 m hinged positive pressure vent installed in a recess in the ceiling was weighted down with a 20-pound cinder block for this test program. The ventilation inlet to the enclosure, through **an** underfloor duct, remained closed during this program. Temperature control of the room is provided by a 3.5-ton commercial heat pump unit, the inlet and outlet of which are each equipped with closable shutters. The exhaust system is also fitted with a closable shutter.

INSTRUMENTATION

<u>Nozzle pressure</u> was monitored with an Ashcroft Model K17MO215F2-300 pressure transducer with a range of 0-300 psig (10-31 VDC input, 1-5 VDC output).

<u>Cylinder pressure</u> was monitored with an Ashcroft Model K17MO215F2-500 pressure transducer with a range of 0-500 psig (10-31 VDC input, 1-5 VDC output).

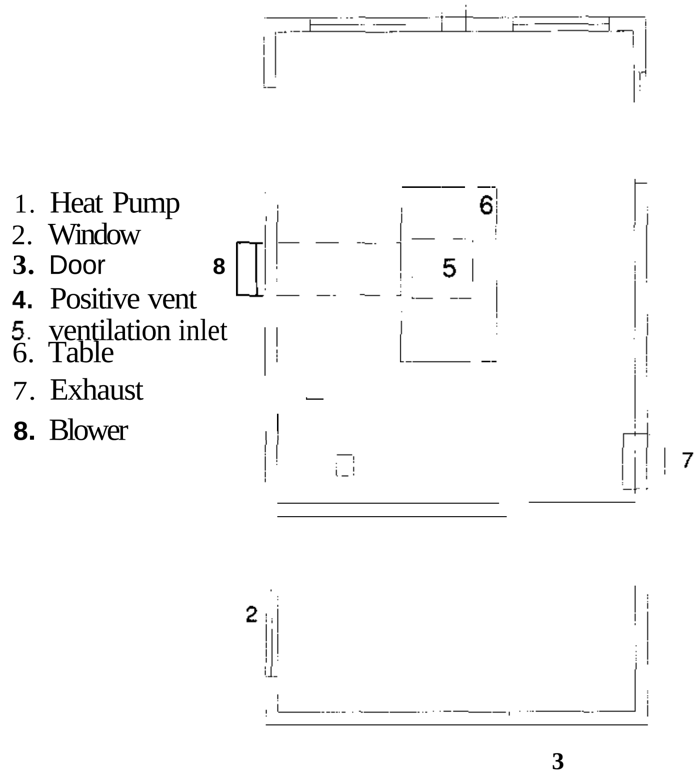

Figure 1. Test facility.

Mass loss were determined by mounting the entire test fire apparatus on an Omega Model LC2-24x24-150 load cell.

Temperatures were measured employing Omega Type K thermocouples.

Data acquisition was accomplished with an Omega DaqBook 100 data acquisition system, equipped with a 16-channel universal voltage/current input card (OMB-DBK-15), a 2-channel strain gage input card (OMB-DBK-16), and a 14-chanel thermocouple input card (OMB-DBK-19). The software package employed was DaqView, version 5.0.

PVC cable: Three samples of 600 volt type NM-B 12/2 with ground PVC cable were employed. Sources were Essex cable (1000 foot rolls) and two different samples of cable from General Cable. The heat of combustion of the cables was determined by cone calorimetry at Hughes Associates, Inc., and found to be 11.5 MJ/kg for the Essex material and 14 and 15 MJ/kg for the General Cable products.

Cable travs: With the exception of the LPC tray, all trays were 9 inches wide by 24 inches in length.

- LPC tray: For Tests 1 through **3,** an 18-inch long sample of galvanized perforated tray obtained from the LPC was employed.

- Ladder tray: For Tests **8** through 16, rungs were removed from a sample of 9-inch wide Chalfant ladder tray (with 9 inch rung spacings), and remounted to yield a rung spacing of 6 inches. All remaining ladder tray tests employed B-Line 9-inch wide ladder tray, with 6-inch rung spacings, either aluminum (B-Line 14A0609144) or pre-galvanized (B-Line 148P0609144).
- Ventilated trough tray: B-Line ventilated trough tray, 9 inches wide. was employed, either aluminum (B-Line 14AVT09144) or pre-galvanized (B-Line 148PVT09144).
- Channel tray: B-Line channel tray, aluminum (B-Line A-CC-06-144) or pre-galvanized (6-Line P-CC-06-144).
- Swifts medium duty tray: Swifts of Scarborough, Ltd, 225 mm wide, 1.0 mm thick medium duty range flange cable tray (Swifts MRFL/225/PG).

SUPPRESSION SYSTEM

FM-200®, superpressurized with nitrogen to 360 psig at 70 °F, was discharged from a Kidde 200-pound cylinder equipped with an electronic/manual actuation unit. System design was accomplished with the Kidde Clean Agent Flow Calculation Program version K 2.10, developed by Hughes Associates, Inc. **A** discharge time of 9-10 sec was employed in all rests; all tests employed a KF302 nozzle. The required weight of FM-200'' was calculated from the relationship:

$$W = \frac{V}{S} \times \frac{C}{100 - C}$$

where W is the required weight of agent in pounds, C is the desired concentration of agent in % v/v, V is the volume of the enclosure (4061 ft^3), and S is the specific volume of the superheated FM-200® vapor at 1 atmosphere pressure and 70 °F (2.2075 ft^3/lb).

EXPERIMENTAL PROCEDURE

Cable trays were mounted on top of the load cell and filled with 24-inch lengths of PVC cable. Three loading configurations were examined:

- Open: Cables placed **in** tray with space left between each cable.
- Random: Cables placed in tray in random fashion, stacked and covering entire width of tray.
- Loose Bundle: Cables stacked in central portion of tray, leaving approximately 1 inch between the cable bundle and the side walls of the tray.

Ignition of the cables was accomplished via a heptane pilot fire. **An** aluminum pan located 1 inch beneath the cable tray was filled with water and heptane and then ignited via an electric match. During the tests, the enclosure door was open and the exhaust fan was on. In the case of extinguishment tests, the enclosure door was open and the exhaust fan on during the preburn, and at 15 sec prior to system activation the door was closed, the exhaust vent closed, and the exhaust fan turned off. Cable tray fires of'the three configurations were examined under a variety of conditions in which the fire load (number of cables) and preburn period were varied. Photographs of each fire were taken at 30-sec intervals to assist in selection of an appropriate set of conditions.

RESULTS AND DISCUSSION

The experimental results are summarized in Tables land 2. Fire sizes were determined from the mass loss curves employing a time period ranging from approximately 10 sec after the heptane pilot fire bumout to 70 sec after the heptane pilot fire bumout. In general, prebum periods of 30 or 60 sec were found to be too short, resulting in weak fires once the heptane pilot fire burned out. The heat release rates (fire sizes) for PVC cables burning in cable trays were found to be dependent upon the type of cable tray and the arrangement of the cables within the tray.

Cable fires in the ladder type trays were more intense when the cables were placed in the tray in a random fashion, **i.e.**, with cable extending to the sides of the tray and in several layers. Fire sizes for this arrangement ranged from 14 to 22 kW, with an average fire size of 19 kW (Tests 41 through 46). An open cable arrangement, which afforded maximum oxidant/fuel contact, led to most of the fuel being consumed during the preburn, and as a result a very weak fire following burnout of the heptane pilot fire. Loose bundling of the cables, which limits fuel/oxidant contact, led too less fuel combusted during the preburn and hence smaller fires following bumout of the heptane pilot fire (e.g., ***5*** kW for Tests 59 and 60).

Cable fires in the ventilated trough were of approximately the same intensity for random (18 kW, Test 58) or loosely bundled cables (range of 12 to 22 kW, Tests ***52*** to 57). **As** was the case for the ladder **type** trays, an open arrangement of cable, which affords maximum oxidant/fuel contact, led to most of the fuel being consumed during the prebum, and as a result a very weak fire following burnout of the heptane pilot fire.

Note from Table 2 that 5.8% FM-200® afforded rapid extinguishment of the various cable tray fires. This included the unrealistic configuration suggested by the LPC (Tests 62, 77, and 78) in which six cable trays are stacked 0.75 inches on top of one another.

This stacked configuration was selected by the ISO 14520 task group for consideration for inclusion in the ISO 14520 standard due in part to its representing a worst-case configuration. **A** survey of both European and U.S. cable tray installers and producers indicated that this stacked configuration is not encountered in the field as it prevents maintenance of the tray system; in fact, such a configuration would be a violation of the National Electrical Code. Cable trays are often mounted on top of each other, but with one to two foot spacings between each tray, again to allow for maintenance. Furthermore, the perforated tray (Swifts) employed in this configuration is not commonly employed for power cables: both US and European producers indicated that the vast majority of applications involving EDP or telecommunication facilities employ the ladder type cable tray. In the event that the ladder type tray is unsuitable, e.g., for small power cables that could droop down from a ladder tray, ventilated trough type trays are the next most commonly employed tray configuration.

CONCLUSION

Suitable test protocols were developed for PVC cable fires in ladder and ventilated trough cable trays. The protocols produce **fires** that are reproducible and exhibit a constant heat release rate following a heptane-induced prebum period of 90 sec. These fires produce sufficient smoke to allow for their detection well before the system activation times proposed in the protocol, and hence represent worst-case conditions.

TABLE 1. PVC CABLE TRAY FREEBURN TESTS.

Test	Cable Tray Type	Cable # Pieces	Load Type	ml heptane	ml H_2O	Prehurn time (sec)	Fire Sire kW	Self Ext. Time (sec)
ISO1	LPC	12	open	85	1000	60	7	200
ISO8	Al ladder (Chalfant)	12	open	130	1000	90	< 5	150
IS09	Al ladder (Chalfant)	12	open	85	1000	*60*	< 5	90
IS010	Al ladder (Chalfant)	12	open	25	1000	30	< 5	60
ISO11	Al ladder (Chalfantj	12	open	25	1000	30	< 5	120
IS012	Al ladder (Chalfant)	2 of 12	open	85	1000	60	< 5	I20
IS013	Al ladder (Chalfant)	24	loose	85	1000	60	13	300
ISO14	Al ladder (Chalfant)	24	loose	130	1000	90	9	360
ISO15	Al ladder (Chalfant)	24	random	85	1000	60	13	330
ISO17	Galv. 6 inch channel	24	open	90	*500*	70	< 5	90
ISO18	Galv. 6 inch channel	24	open	150	500	101	< 5	210
ISO19	Galv. 6 inch channel	12	loose	85	500	60	< 5	150
ISO20	Al Vented Trough	24	loose	150	**500**	106	12	360
ISO21	Galv. Vented Trough	24	loose	120	***500***	85	X	330
ISO22	Galv. Vented Trough	24	loose	85	*500*	60	10	240
IS023	Galv. Vented Trough	24	loose	*55*	**500**	*53*	6	270
ISO24	Galv. Vented Trough	24	loose	25	1000	32	< 5	270
IS025	Galv. Vented Trough	I2	open	25	1000	32	< 5	120
IS026	Galv. Vented Trough	12	open	85	1000	60	< 5	180
IS027	Galv. Vented Trough	12	open	130	1000	90	< 5	210
ISO28	Al Vented Trough	24	open	25	1000	35	< 5	60
IS029	Al Vented Trough	24	loose	X5	1000	5x	9	300
IS030	Al Vented Trough	24	loose	130	1000	90	14	330
IS031	Al Vented Trough	12	open	25	1000	30	< 5	30
IS032	Al Vented Trough	12	open	85	1000	57	< 5	180
IS033	Al Vented Trough	12	open	130	1000	x7	< 5	180
IS034	Al ladder	24	random	85	1000	64	< 5	*150*
IS035	Al ladder	24	loose	85	1000	65	< 5	180
IS036	Al ladder	24	loose	85	1000	60	< 5	120
IS037	Al ladder	24	loose	130	1000	88	11	300
IS038	Al ladder	24	random	130	1000	85	10	210
ISO39	Al ladder	24	loose	130	1000	*85*	3	330
ISO40	Al ladder	24	loose	130	**1000**	90	*5*	240
IS041	Al ladder	32	random	130	1000	93	22	240
IS043	Al ladder	32	random	130	1000	XX	18	270
IS044	Al ladder	32	random	I30	1000	93	17	240
ISO47	Galv. ladder	32	random	130	1000	89	22	300
ISO58	Galv. Vented Trough	24	random	I30	**1000**	85	25	210
IS059	Al ladder	32	loose	130	1000	90	< 5	250
IS060	Al ladder	32	loose	130	1000	90	< 5	360
ISO61	Al Swifts medium service	6 of 10	open	130	1000	90	25	555

TABLE 2. EXTINGUISHMENT OF PVC **CABLE** FIRES WITH ***5.8%*** V/V FM-200®.

Test	Cable Tray Type	Cable# Pieces	Load Type	ml heptane	ml H_2O	Prebum time, sec	Fire Size, kW	Ext. Time, s
IS016	**Al** ladder	**24**	random	90	500	60	10	25
IS042	**Al** ladder	32	random	130	1000	90	19	6
IS045	**Al** ladder	32	random	I30	1000	88	14	5
IS046	**Al** ladder	32	random	130	1000	85	22	7
IS048	Galv. ladder	32	random	130	1000	85	25	22
IS049	Galv. ladder	32	random	130	1000	87	17	6
IS050	Galv. ladder	32	random	130	1000	85	15	8
IS051	Galv. Vented Trough	24	loose	85	1000	65	4	9
IS052	Galv. Vented Trough	**24**	loose	130	1000	94	10	9
IS053	Galv. Vented Trough	24	loose	130	1000	85	13	8
IS054	Galv. Vented Trough	24	loose	I30	1000	93	22	9
IS055	**Al** Vented Trough	24	loose	130	1000	90	**12**	7
IS056	**Al** Vented Trough	24	loose	130	1000	89	15	6
IS057	**Al** Vented Trough	24	loose	130	1000	88	13	6
IS062	**Al** Swifts medium	6 of 10	open	130	1000	90	28	20
IS063	**Al** ladder	32	random	130	1000	85	34	36
IS064	**Al** Vented Trough	24	loose	130	1000	85	22	21
IS077	**Al** Swifts medium	*6 of 10*	*open*	130	1000	90	30	28
IS078	**Al** Swifts medium	6 of 10	open	130	1000	90	26	35

It was observed that 5.8% FM-200 afforded rapid extinguishment of these cable tray fires, and could even afford extinguishment of unrealistic cable configurations in which multiple cable tray units were stacked on top of one another. This stacked configuration has been selected by the ISO 14520 task group for consideration for inclusion in the ISO 14520 standard due in part to its representing a worst-case configuration.