SCHULTE & ASSOCIATES
Building Code Consultants
880D Forest Avenue
Evanston, IL 60202
fpeschulte@aol.com
504/220-7475

SUMMARY

LARGE SCALE TESTS OF SPRINKLER, VENT, DRAFT CURTAIN INTERACTION (1998)

Kevin McGrattan
National Institute of Standards and Technology
Gaithersburg, MD 20899, USA

David Sheppard
Underwriters Laboratories, Inc.
333 Pfingsten Road
Northbrook, IL 60062, USA

The International Fire Sprinkler, Smoke & Heat Vent, Draft Curtain Fire Test Project organized by the National Fire Protection Research Foundation (NFPRF) brought together a group of industrial sponsors to support and plan a series of large scale tests to study the interaction of sprinklers, roof vents and draft curtains of the type found in large warehouses, manufacturing facilities, and warehouse-like retail stores. Representatives from the sponsoring organizations, the National Institute of Standards and Technology (NIST), and other interested parties planned 39 large scale fire tests that were conducted in the Large Scale Fire Test Facility at Underwriters Laboratories (UL) in Northbrook, Illinois. (Page 1)

The committee selected one sprinkler, roof vent, draft curtain design for installation in the test facility in order to simulate fire protection systems found in warehouses, warehouse retail stores and manufacturing facilities. **The objective of the project was to investigate the effect of roof vents and draft curtains on the time, number, and location of sprinkler activations; and also the effect of sprinklers and draft curtains on the activation time, number, and discharge rates of roof vents**. (Page 1)

In all, 39 tests were specified by the committee. **All 39 tests were conducted in the Large Scale Fire Test Facility at Underwriters Laboratories (UL) in Northbrook, Illinois.** (Page 1)

The Large Scale Fire Test Facility at UL contains a 37 m by 37 m (120 ft by 120 ft) main fire test cell, equipped with a 30.5 m by 30.5 m (100 ft by 100 ft) adjustable height ceiling. The height of the ceiling may be adjusted by four hydraulic rams up to a maximum height of 14.6 m (48 ft). (Page 2)

Draft curtains (denoted by dashed lines in Figs. 1 and 2) 1.8 m (6 ft) deep were installed for 16 of the 22 tests in Heptane Series I, all of the tests in Heptane Series II, and 3 out of 5 tests in the Plastic Series. The curtains were constructed of 1.4 m (54 in) wide sheets of 18 gauge sheet metal. The seams in the draft curtains were connected with aluminum tape. The area of the largest quadrant in Fig. 2 was selected to provide a larger vent to floor ratio (1:42) than called for by the Uniform Fire Code (1:50 for up to 6.1 m (20 ft) of storage height and less then 560 m^2 (6000 ft^2) of curtained area) [4]. (Page 2)

The sprinklers used in all the tests were Central ELO-231 (Extra Large Orifice) uprights. The orifice diameter of this sprinkler was reported by the manufacturer to be nominally 16 mm (0.64 in), the reference actuation temperature was reported by the manufacturer to be 74°C (165°F). The RTI (Response Time Index) and C-factor (Conductivity factor)[1] were reported by UL to be 148 $(m\text{-}s)^{1/2}$ (268 $(ft\text{-}s)^{1/2}$) and 0.7 $(m/s)^{1/2}$ (1.3 $(ft/s)^{1/2}$), respectively [1]. When installed, the sprinkler deflector was located 8 cm (3 in) below the ceiling. The thermal element of the sprinkler was located 11 cm (4.25 in) below the ceiling. The sprinklers were installed with 3 m by 3 m (10 ft by 10 ft) spacing in a system designed to deliver a constant 0.34 $L/(s\text{-}m^2)$ **(0.50 gpm/ft^2) discharge density** when supplied by a 131 kPa (19 psi) discharge pressure. (Page 3)

UL-listed double leaf fire vents with steel covers and steel curbs were installed in the adjustable height ceiling in the positions shown in Figs. 1 and 2. The vent design was selected in collaboration with the NFPRF Technical Advisory Committee who sponsored the large scale tests. The vent doors were recessed into the ceiling 0.3 m(1 ft). **The vents were designed to open manually or automatically. In tests where automatic operation of the vents was desired, UL-listed fusible links rated at either 74°C (165°F) or 100°C (212°F) were installed. In most tests, the 74°C link was used.** (Page 3)

The Factory Mutual Research Corporation (FMRC) Standard Plastic test commodity, a Cartoned Group A Unexpanded Plastic, served as the fuel for the cartoned plastic commodity series. This commodity has been used extensively for testing since 1971 [7]. It consisted of rigid crystalline polystyrene cups (empty, 0.47 L (16 fl oz) size) packaged in compartmented, single-wall, corrugated paper cartons. The cups were arranged open end down in five layers, 25 per layer for a total of 125 per carton. Each carton, or box, was a cube 0.53 m (21 in) on a side. Eight boxes comprised a pallet load. Two-way, 1.06 m by 1.06 m by 0.13 m (42 in by 42 in by 5 in) slatted deck hardwood pallets supported the loads. A pallet load weighed approximately 80 kg (170 lb), of which about 36% was plastic, 35% was wood and 29% was corrugated paper [7]. A Class II commodity was used in the target arrays beyond the expected area of the fire spread. This commodity consisted of double tri-wall corrugated paper cartons with five-sided steel stiffeners inserted for stability. The two cartons plus the liner formed a single 1.06 m (42 in) cube having a combined nominal wall thickness of 2.5 cm (1 in). (Page 3)

The fire was ignited with 2 standard igniters which consisted of 8 cm (3 in) long by 8 cm diameter cylinders of rolled cotton material, each soaked in 120 mL (4 oz) of gasoline and enclosed in a polyethylene bag. The rolls were placed just above the pallet against the carton surfaces in the first tier of the main array, halfway down the transverse flue. The igniters were lit with a flaming propane torch at the start of each test. (Page 5)

When the fire was not ignited directly underneath a vent, the activation times of the nearest sprinklers to the fire were not affected by the opening of vents either prior to or after the first sprinkler activation. When the fire was ignited 3 m (10 ft) from the vent center, the only discernible affect of the vent opening on sprinkler activation was for those sprinklers immediately downstream of the vent. (Page 5)

In tests where the fire was ignited directly beneath a vent, vent openings prior to the activation of the nearest sprinklers had an effect on the sprinkler activation times. The earlier the vent opening, the more noticeable the effect. . . . .**This data suggests that the earlier the vent activation, the longer the delay in activation of the first ring of sprinklers.** (Page 5)

During the second series of heptane spray burner tests, two tests were performed with the burner directly under a vent. In Test II-7, where the vent was held closed, the average activation times of the nearest two sprinklers was 1:14 and the nearest six 1:24. In Test II-3, where the vent opened automatically at 1:15, the average of the nearest two sprinklers was 1:17 and the nearest six 1:32. (Page 6)

In general, draft curtains increased the number of sprinkler activations. Inspection of Table 1 indicates that in Tests I-1 and I-8 there were 11 ac-tivations when the draft curtains were installed and the vent was closed, and in Test I-17 there were 4 activations when the curtains were not installed and the vent was closed. Tests I-4 and I-7 both had 10 activations with the curtains installed and the vent closed, Tests I-18 and I-21 had 4 and 10 activations with the curtains removed. Tests I-9 and I-10 had 12 and 13 activations with curtains installed, Test I-22 had 6 activations with the curtains removed. **This data indicates that in tests performed with draft curtains where the fire was not directly beneath a vent, there were up to twice as many sprinkler activations compared to tests performed without draft curtains.** (Page 7)

The reason for the increased number of activations is that draft curtains lead to an increase of the near ceiling gas temperatures. Consider, for example, the peak gas temperatures near the second ring sprinklers in Test I-1 compared to those of Test I-17. The temperatures were between 20ºC and 30ºC (36ºF and 54ºF) lower in Test I-17. Similar differences can be seen when comparing temperatures in Tests I-1 through I-16 with those in Tests I-17 through I-22. The difference between temperatures in the curtained and uncurtained tests can be explained by considering a fire plume impinging on a well-developed, 1.8m (6 ft) deep smoke layer as opposed to a thinner layer. **In the latter case, the plume can entrain more cool air before it reaches the ceiling layer, and therefore the smoke is cooler by the time it reaches the ceiling. Plus, the deeper smoke layer formed by the draft curtains insulates the sprinklers from cooler air below the layer, leading to more activations.** (Page 7)

What effect did the vents have on the number of activations? **When the fire was ignited directly under a vent (Position A), the number of activations was reduced.** Consider Test I-12 versus Tests I-13, I-14, I-15 and I-16. The number of activations was roughly halved due to the opening of the vent directly above the fire. Tests II-3 and II-7 show the number of activations reduced from 18 to 12. **However, when the fire was not ignited under a vent, there was either a small decrease or no decrease at all in the number of sprinkler activations. . . . .Thus, unless the ignition took place under or very near a vent, there was no evidence in this data set that venting reduced the number of sprinkler activations.** (Page 7)

In the cartoned plastic commodity Test P-3, **the draft curtain to the north of the ignition point delayed the operation of sprinklers further north and blocked the spray of sprinklers on either side of it.** In this test, the fuel array extended beneath the north and west curtains. The fire spread to the north side of the main array because the commodity there was unwetted due to a delay in sprinkler activation on the north side of the curtain and blockage of the sprinkler spray from the south side. **The results of Test P-3 reinforced evidence provided by two similar tests performed by Factory Mutual [7]. In the FMRC tests, the fires spread underneath the curtains, resulting in the development of a more severe fire, a greater number of sprinkler operations, an atypical sprinkler opening pattern, distorted sprinkler discharge patterns which affected prewetting of commodity, and more smoke production. Although the fire damage and number of sprinkler activations in Test P-3 were not as great as that seen in the tests performed at FMRC, the fire damage was substantially higher in this test than in any other test performed in the series, even though the first two sprinkler activations were relatively early (67 and 72 s). This early activation was most likely due to the close proximity of the fire to the intersection of the draft curtains**. However, the early jump on the fire did not lead to a rapid decrease in temperatures or sprinkler activations as was the case in Tests P-4 and P-5, the other two tests performed with draft curtains installed. Instead, the fire spread to the unprotected north face of the central array; and even though it was eventually controlled by sprinklers on the north side of the east-west curtain, it ultimately consumed approximately 184 boxes, **nearly twice as much as Tests P-4 and P-5. A vent did automatically activate at 4:11, but by that time the two sprinklers on each side of it had already activated. Based on an examination of the sprinkler activation pattern and the thermocouple data, the opening of the vent had no influence on the test results**. (Page 8)

Based on the test data collected in this study, it is difficult to assess how, in general, sprinklers affect the activation of vents because (1) there is little information about how the vents would have operated in an unsprinklered facility because only one test was performed without sprinklers, and (2) only one vent design was used in the test program. However, **it appears from the data below that the sprinkler spray influenced the thermal response characteristics of this particular vent, and it is believed that sprinklers could have a similar influence on comparable vent designs.** (Page 8)

In Plastic Test P-2, the fire was ignited directly under a vent. **In the experiment, flames reached the top of the central array at about 65 s and the vent cavity at about 70 s. The first sprinkler activated at 100 s. The vent did not open at any time during the 30 min test even though another vent 6 m (20 ft) to the west of the unopened vent opened at 6:04.** (Page 9)

The significant cooling effect of sprinkler sprays on the near-ceiling gas flow often prevented the automatic operation of the vents. This conclusion is based on thermocouple measurements within the vent cavity, the presence of drips of solder on the fusible links recovered from unopened vents, and several tests where vents remote from the fire and the sprinkler spray activated. In one cartoned plastic commodity experiment, **a vent did not open when the fire was ignited directly beneath it.** (Page 10)

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