A Study of Sprinkler Sensitivity

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How does beam and girder ceiling construction affect the response time of automatic sprinklers, and what is the effect of various ceiling-to-deflector distances? These are questions the authors sought to answer in their investigation.

THE National Automatic Sprinkler and Fire Control Association conducted a series of tests to determine the effect of beams on operating or response time of automatic sprinklers at various levels below a ceiling. The problem of the proper sprinkler deflector distance below the ceiling has been complicated by the introduction of a type of construction in which beams of various depths are spaced 3 to 4 ft apart. Strict adherence to current sprinkler rules regarding deflector distance in the Standard for the Installation of Sprinkler Systems (NFPA No. 13) has resulted in extremely close spacing of sprinkler piping and sprinklers.

A review of available test data and reports indicated no previous investigation had been made regarding beam effect on sprinkler operation. Underwriters' Laboratories, Inc., conducted a test series in 1955 entitled "Comparison of Operation of Fire Alarm Thermostats Under Smooth Ceiling and Open-Joisted Construction." One of the conclusions reached in this test series was that thermostats should be installed at the bottom of wood joists, rather than in the channel between joists. Thermostats located in the joist channel were invariably slower to respond than thermostats located at the bottom of the joists.

OBJECT AND TEST CONDITIONS

This test series was designed to develop basic beam effect data and to evaluate the deflector distance rules for beam and girder construction in NFPA No. 13 by comparing the average response time of automatic sprinklers installed at distances varying from 3 in. to 48 in. below smooth ceiling and beam-type construction.

The test area was 30 ft wide by 40 ft long, had a smooth concrete ceiling 26 ft high, and was enclosed on three sides. The north side of the area

NOTE: Serving with Mr. Campbell on this Committee were P. H. Merdinyan, Robert Duke, John Norcliffe, and Wendell Persing.

was open to an adjacent test area from the floor to within 11 ft of the 26-ft high ceiling. Beams 18 in. and 36 in. deep were simulated by plywood and installed at the ceiling. Solder-type sprinklers with ordinary and high-temperature ratings were used.

Sprinkler operating times were measured under the following types of ceiling construction — smooth ceiling (preliminary tests), 18-in. beams without flanges and set on 3-ft centers, 18-in. beams with 12-in. flanges and set on 3-ft centers, 36-in. beams with 12-in. flanges and set on 3-ft centers, 36-in. beams with 12-in. flanges and set on 6-ft centers, 36-in. beams without flanges and set on 6-ft centers, and smooth ceiling. All tests were conducted with sprinklers installed in a dry pipe rack as shown in Figure 1.

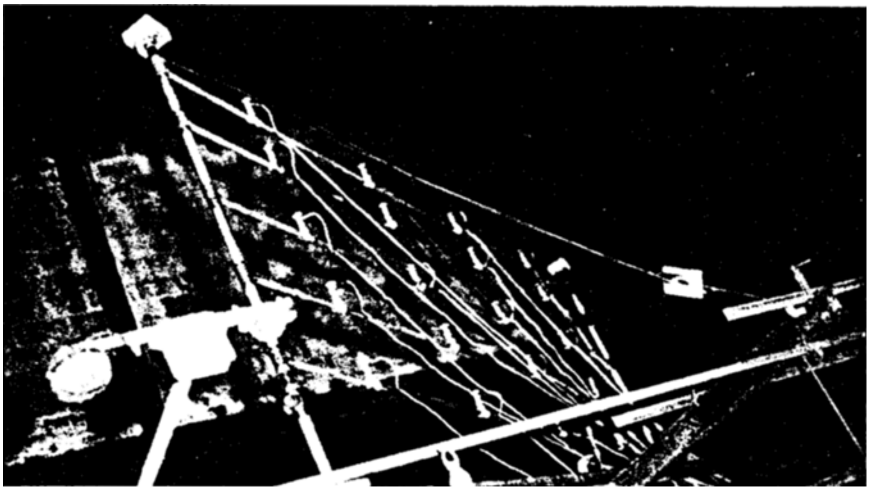

Figure 1. One bank of 20 sprinklers used in the tests.

Eight preliminary smooth ceiling tests were conducted to develop test procedures, size and location of fires, and general relationships between deflector distance and time of operation. Each test in this series was conducted with vertical rows of sprinklers hung at four different distances from a fire in the corner of the test room (See Figures 1 and 2). The test was continued until all 20 sprinklers had operated. Separate tests were conducted with ordinary and high-temperature-rated sprinklers.

For Tests Nos. 1–27, the sprinklers were arranged in two banks. Each bank consisted of seven levels with four sprinklers spaced 2 ft apart at each level. The seven levels of sprinklers were spaced vertically so that their deflectors were 3, 12, 16, 20, 24, 36, and 48 in., respectively, below the ceiling (see Figure 3). Under simulated beam construction, the banks of sprinklers were installed in the center of alternate bays when the beams were spaced 3 ft apart (see Figure 4), and in the center of adjacent bays when the beams were spaced 6 ft apart. Under smooth ceiling, the banks were spaced 6 ft apart.

Each sprinkler was connected to an electric pilot light so that when a sprinkler operated, its response time could be determined. Solox* was used as a fuel in either one or two 9-sq-ft pans. The location of the pans and the quantity of Solox burned varied with the type of test. Temperature recording thermocouples were installed in the test area.

Tests 1–10 were conducted with two banks of sprinklers at a fixed location in the room (see Figure 4). The fire was placed at various locations to determine the most significant effect. At the completion of these tests, a

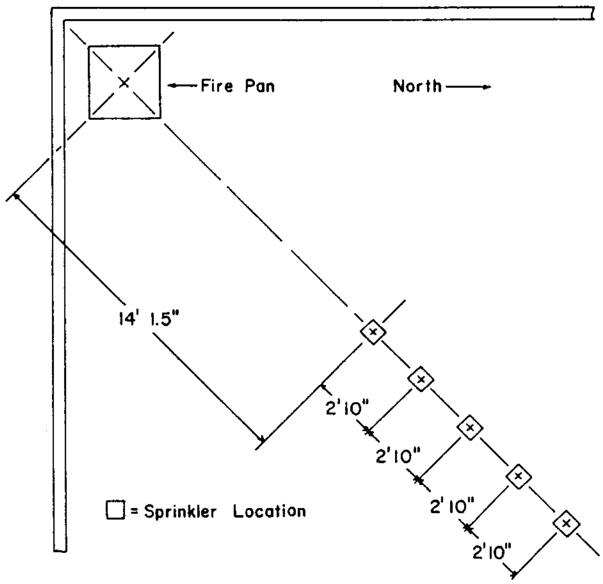

Figure 2. Plan view for preliminary smooth ceiling tests.

fixed test fire location was selected for the remaining tests. The arrangement shown in Figure 5 was used for Tests Nos. 11–22. The fire was located 10 ft from the end walls. Beam depth, configuration, and spacing were varied. Smooth ceiling tests, Tests Nos. 23–27, were made under conditions similar to those employed for Tests Nos. 11–22 as a basis for establishing smooth ceiling test data.

TEST PROCEDURE

Each sprinkler rack included 28, ½-in. tees. Facilities were available in the test building for raising and lowering the rack (see Figure 3). Sprinklers were installed in the test rack and connected to individual pilot lights in test panels. The integrity of the connections was verified by the pilot lights being lit (see Figure 5). The pipe racks were then raised to the ceiling. The design of the racks was such that, when raised, the sprinklers would automatically be at the deflector distances noted under "Test Conditions." The test fire was then lighted. As each sprinkler operated, its electrical connection to the test panel was broken and its respective pilot

*Solox is the trade name for a general purpose solvent made by the U. S. Industrial Chemicals Co.

light was extinguished. The time lapse from the beginning of the test to the sprinkler response was noted and recorded. At the completion of each test, the doors were opened, test racks were lowered, and new sprinklers were installed. This procedure allowed ceiling and building temperatures to cool to acceptable levels before starting the next test.

TEST RESULTS

The results of each group of tests are summarized as follows.

- Tests Nos. 1–10 (18-in. beams without flanges and spaced 3 ft on centers) — Although specific operating time range varied, the average response for sprinklers with deflector distances from 12 in. to 24 in. were reasonably consistent with each other. In general, sprinklers above 12 in. responded faster; those below 24 in., slower. Tests 3, 7, and 8 were exceptions to this tendency.

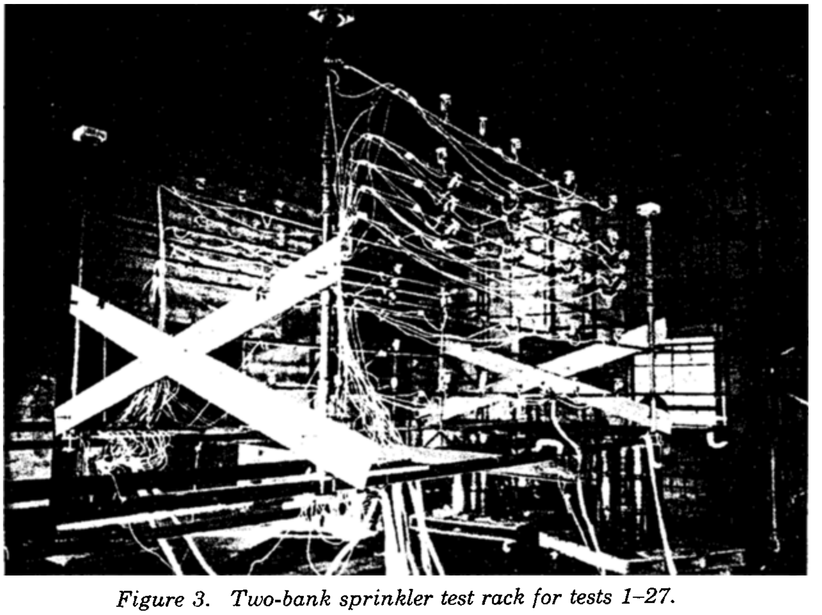

Figure 3. Two-bank sprinkler test rack for tests 1–27.

- Tests Nos. 11–13 (18-in. beams with 12-in. flanges and spaced 3 ft on centers) — Average sprinkler response time for Test 11 was relatively consistent throughout all deflector distances. In Tests 12 and 13, the fastest operating time was at the 36-in. deflector distance level.
- Tests Nos. 14–15 (36-in. beams with 12-in. flanges and spaced 3 ft on centers) — Insufficient data were obtained from the next four tests conducted to be of any value. In Tests 14 and 15, the relative response for sprinklers with deflector distances of 12 in. to 24 in. were in a consistent pattern. Sprinklers above 12-in. deflector distances responded approximately 20 per cent faster than those in the 12-in. to 24-in. range, while those below 24 in. responded 6 to 8 min (approximately 30 to 50 per cent) faster.

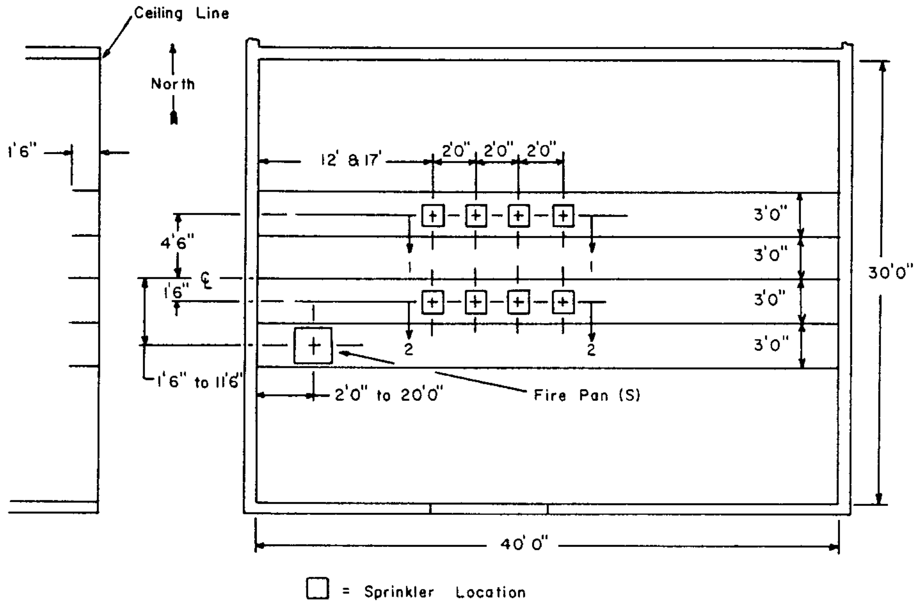

Figure 4. Plan view for tests 1–10.

- Tests Nos. 16–19 (36-in. beams with 12-in. flanges and spaced 6 ft on centers) — Sprinklers at the 3-in. and 48-in. deflector distances responded at essentially the same time. The response of intermediate sprinklers was increasingly slower as the distance increased from 3 in. or 48 in.
- Tests Nos. 20–22 (36-in. beams without flanges and spaced 6 ft on centers) — The slowest average response was by sprinklers with deflector distances at 20 in. Response time decreased both above and below the 20-in. level. In Test No. 20, the fastest response time was obtained at the 3-in. level, and in Tests 21 and 22, at the 48-in. level.
- Tests Nos. 23–27 (smooth ceiling) — The results of these tests were consistent. The fastest response was at the 3-in. deflector distance below the ceiling. As the distance increased, the response time also increased.

CONCLUSIONS

Under smooth ceiling construction, the fastest operation is at the 3-in. deflector distance. Operating time increases with increased distance from the ceiling.

Under beam and girder construction with the fire in the bay, the fastest operation is at the 3-in. deflector distance. Operating time increases with increased distance from the ceiling.

Several conclusions can be drawn from the tests involving beam and girder construction with the fire in an adjacent or otherwise remote bay. The areas for fastest operation are close to the ceiling (3-in. deflector distance) and below the bottom level of the beams. The areas for slowest operation are above the bottom level of the beams, but at a deflector distance

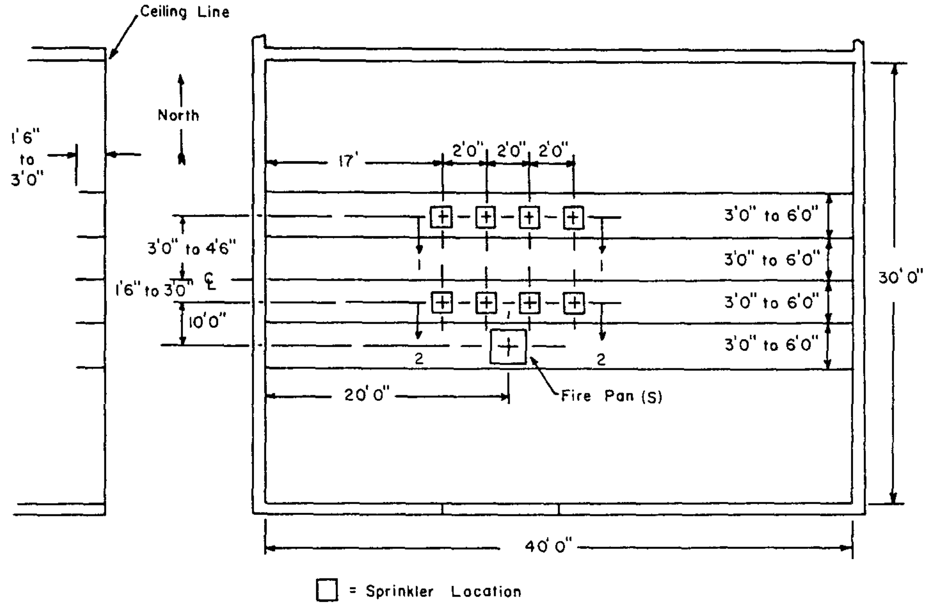

Figure 5. Plan view for tests 11–22.

of 12 in. or more. The interference presented by the beams tends to increase sprinkler operating time over that for a smooth ceiling. Variations in beam spacing and flange width have no significant effect on sprinkler operating time. The pattern of operation is no different for ordinary or high-temperature sprinklers.

SUMMARY

The effectiveness and reliability of automatic sprinklers have established the automatic sprinkler system as the most effective deterrent to the loss of life and property from fire. The automatic sprinkler is but one of many components that, along with system design criteria, have contributed to the outstanding service record.

This study was made to investigate one aspect of system design; namely, the sensitivity or relative operating times of sprinklers under beam and smooth ceiling constructions at varying ceiling-to-deflector distances. Sprinkler sensitivity or its response to fire conditions is a function of temperature rating, inherent thermal lag, fire conditions, and installation

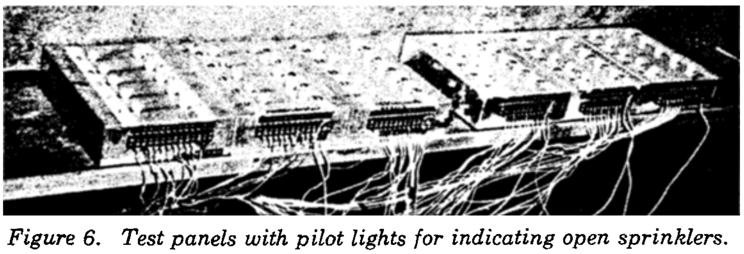

Figure 6. Test panels with pilot lights for indicating open sprinklers.

relative to building structural configuration. Sprinklers may have varying sensitivity depending on the particular design. These differences — measurable under carefully controlled laboratory tests — are nullified under actual fire conditions. Thus, full-scale fire testing has an averaging effect, and the results of this study are applicable to all listed and approved automatic sprinklers.

There now remains the question of whether fire protection capability could be adversely affected by these new system considerations. A separate study of water discharge characteristics must be conducted under similar variables before any final conclusions can be drawn. In view of the results contained in this report, it would appear that such a study is warranted.

ACKNOWLEDGMENT: The Committee is indebted to the Grinnell Company for the use of its Cranston, Rhode Island, facilities and for technical assistance. The tests were conducted in the high section of Grinnell's Test Center.