RESEARCH FOUNDATION

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ESFR Sprinklers and Obstructions – Phase 3

Executive Summary

22 December 2016

The goal of the Obstructions and ESFR Sprinkler research project is to ultimately develop a tool which could be used to provide the reliable analysis of the impact of obstructions on ESFR sprinkler performance. Phases 1-3 focused on developing an understanding of the effect various obstruction scenarios have on ESFR sprinkler performance. Eight full-scale and approximately 40 Actual Delivered Density (ADD) tests have been completed to date.

Phase 3 of the project targeted vertical obstruction separation. In addition, obstruction width and shape were considered. The intent was to expand the understanding of miscellaneous obstructions and how different shapes of obstructions affect sprinkler discharge. Both ADD and full-scale testing were conducted.

Various arrangements of obstruction widths and shapes were tested to measure the change in ADD from the baseline condition (unobstructed sprinkler). The obstructions ranged in width from 3 to 12 inches. Both round and flat shapes were used. To better understand the results of the ADD work, the obstruction scenarios were plotted against ESFR sprinkler discharge patterns. This analysis showed that for obstructions located directly below the sprinkler, the ADD increases as the vertical distance between the sprinkler and the obstruction increases. For obstructions horizontally offset from the sprinkler, the inverse is true, the ADD decreases as the vertical distance between the sprinkler and the obstruction increases.

Full-scale testing was conducted based upon the information gathered in the ADD testing and sprinkler discharge pattern analysis. The results are shown in Table 6. From this work, it is hypothesized that although ADD testing may be used to gain insight into full-scale fire test performance, other variables are involved. For example, two flat obstructions, 6 and 12 inches wide, located 6 inches horizontally from the sprinkler and 20 inches below have very similar ADD test results. However, when both scenarios were tested in full scale, only one sprinkler activated in the 6-inch wide obstruction test and 10 sprinklers activated in the 12-inch wide obstruction test. The test results of the 12-inch wide obstruction showed at least two sprinklers skipped (did not operate). One explanation is that the larger width of the 12-inch wide obstruction caused a larger disruption of sprinkler droplets and thus allowed the fire plume to transport the droplets to adjacent sprinklers, cooling the sprinklers such that operation did not occur. Without further examination of this variable, the understanding of the effect miscellaneous obstructions have on ESFR sprinkler performance will be limited.

From the full-scale fire tests that were conducted, the following conclusions can be made:

1 Batterymarch Park, Quincy, MA 02169-7471
Telephone: +1.617.984.7281 Fax: +1.617.984.7010
Email: Foundation@NFPA.org www.NFPA.org/Foundation

- K17 ESFR sprinklers obstructed by a 1.5-inch x 1.5-inch bridging member located 12 inches directly below the sprinkler produced acceptable results. In conjunction with the results of Phase 2, it can be said that bar joists 26-36-inches deep, 6 inches horizontally offset from the sprinkler with a 1.5-inch x 1.5-inch bridging member located directly under the sprinkler will not significantly decrease the performance of the ESFR sprinkler.
- K17 ESFR sprinklers obstructed by a 6-inch wide flat obstruction located 6 inches horizontally offset and 20 inches below the sprinkler produced acceptable results.
- K17 ESFR sprinklers obstructed by a 12-inch wide flat obstruction located 6 inches horizontally offset and 20 inches below the sprinkler activated 10 sprinklers, 2 sprinklers more than that stated in the pass/fail criteria (reduction in safety factor from 1.5 to 1.2 based upon 12 sprinkler design). The fire damage was acceptable, as were the ceiling temperatures.

The project thus far has led to significant gains in the understanding of obstructions and ESFR sprinkler performance. Going forward, it is vital to better understand sprinkler skipping phenomena as it relates to the characteristics of various obstruction scenarios. Without this information, the miscellaneous obstruction work is incomplete, and the development of the prediction tool is problematic.

For the next phase, it is suggested that additional ADD and full-scale tests be conducted. These tests will be used to fill in data gaps for 12-inch wide obstructions, where only two points were tested, 16 and 20 inches below the sprinkler. Data for smaller vertical clearances is needed. Additionally, using the ADD testing to predict sprinkler skipping will be researched. It is thought that visual observation or other methods may allow the use of ADD testing to provide an indication of the potential for sprinkler skipping. The findings of the ADD testing will then be verified in full scale.

Table 6 – Full Scale Test Results

FIRE TEST NUMBER	Test 1	Test 2	Test 3
Test Date	August 4, 2016	August 9, 2016	August 12, 2016
Obstruction	1½-inch by 1½-inch bridging member, directly under sprinkler, 12 inches down from deflector	12-inch wide, 3-inch deep structural C shape; 6 inch offset from primary sprinkler; 20 inches below deflector	6-inch wide, 2-inch deep structural C shape; 6 inch offset from primary sprinkler; 20 inches below deflector
Test Results			
Length of Test (minutes)	32:00	32:00	32:00
First Sprinkler Operation Time, (min:sec)	1:18	1:22	1:11
Last Sprinkler Operation Time, (min:sec)	1:18	7:06	1:11
Number of Operated Sprinklers	1	10	1
Peak Gas Temperature at Ceiling Above Ignition (°F)	242	217	240
Maximum 1 minute Average Gas Temperature at Ceiling Above Ignition (°F)	143	142	122
Peak Steel Temperature at Ceiling Above Ignition (°F)	92	138	94
Maximum 1 minute Average Steel Temperature at Ceiling Above Ignition (°F)	91	137	94
Fire Travel to Extremities of Test Array	No	No	No
North Target Ignition	No	North target array at approximately 4 minutes, 30 seconds and damaged commodity, but the fire did not travel to the outer plane of this target array.	No