Resolving ESFR Sprinkler Obstruction Challenges

The findings of an industry research project were used as the basis for code changes to the 2022 edition of NFPA 13.

By Garner A. Palenske, P.E.

Early suppression fast response sprinkler (ESFR) technology was introduced in the late 1980s. The ESFR sprinkler was touted as the replacement for in-rack sprinklers. The large orifice size and quick response thermal link are capable of delivering a previously unmatched quantity of water flux to an aggressive storage fire. In addition, ESFR sprinklers are ceiling sprinklers, thus not vulnerable to an inattentive forklift operator.

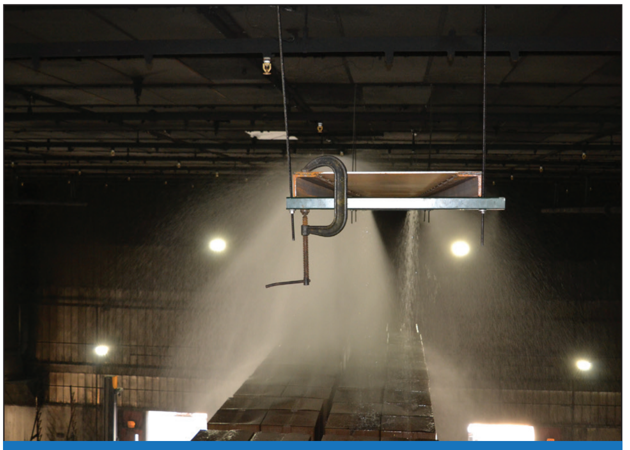
ESFR sprinkler performance came with a price. The early sprinkler design and installation standards published by the National Fire Protection Association (NFPA) and FM Global contained very rigorous obstruction requirements for the installation of ESFR sprinklers. Not only did these requirements complicate the installation of ESFR sprinklers, but they also misrepresented the sprinklers as fragile or unreliable compared to standard spray sprinklers.

However, help was on the way. In 2006, the National Fire Protection Research Foundation commissioned a multiyear research project to sort the ESFR sprinkler obstruction issue. The goal of this project was to validate the current rules for ESFR sprinkler obstructions, and if appropriate, provide data to the NFPA 13 code development committee to submit code changes to align ESFR sprinkler obstruction rules based upon scientific data.

Using Scientific Method to Resolve Sprinkler Obstruction Issues

This project was unique due to the innovative use of the actual delivered density (ADD) apparatus as a scoping tool for full-scale testing. ADD testing is typically used for sprinkler listing or approval. The technology has been around since the 1990s. ADD testing allowed the examination of approximately 65 scenarios from which nine full-scale tests were selected.

ADD testing provides a methodology to identify trends and identify scenarios that may pass or fail the selected performance criteria. Given the wide range of variables included in the project scope, ADD testing



Early suppression fast response sprinkler technology was introduced in the late 1980s. Photo: Wiss, Janney, Elstner Associates, Inc.

proved to be a reliable and consistent tool to quickly and economically simulate full-scale test outcomes.

The work was completed in four distinctive phases, each building upon the tests conducted prior to obtain a comprehensive view of ESFR obstruction phenomena, as guided by the selected boundary conditions.

Phase 1 consisted of a literature search in which relevant research concerning ESFR sprinkler performance and obstruction criteria was collected and reviewed. Potential obstruction scenarios for the testing were also identified.

Given the infinite number of sprinkler obstruction conditions that may occur, boundary conditions for the testing were established. Survey results of NFPA 13 users worldwide showed that open web steel joists are the most commonly used structural roof system. Bridging members, which provide lateral support for maintaining stability under vertical loads, were identified as the most problematic ESFR sprinkler obstruction.

Discussions with leading steel joist suppliers indicated that the most common sizes sold are in the range of 22 inches to 36 inches in depth, with 30 inches deep being the most popular.

The obstruction created by an open web steel truss is dependent on the size of the bottom chord. The upper chord is assumed to be above the sprinkler and thus out of the sprinkler spray pattern. The web of the steel truss is minimal in size, typically 1/2-inch-wide round or L stock and, therefore, is assumed to not influence the sprinkler discharge pattern in a significant manner.

This project was unique due to the innovative use of the actual delivered density apparatus as a scoping tool for full-scale testing, which provides a methodology to identify trends and identify scenarios that may pass or fail the selected performance criteria. Photo: Wiss, Janney, Elstner Associates, Inc.

The chords are constructed of two L-shaped members, welded or bolted together back to back. In addition, the web is attached between the two, increasing the width by approximately 1/2 inch. The width of the bottom chord is a function of the depth of the open web steel joist. Joists 22 inches to 30 inches deep are provided with chords 4-1/2 inches in width, and joists 36 inches deep are provided with chords 5 1/2 inches in width.

The characteristics of the ESFR sprinkler selected for the testing were also determined in Phase 1. Discussions with sprinkler manufacturers were conducted to aid in this selection. Upright-style ESFR sprinklers were found to be of minimal popularity; therefore, pendent-style sprinklers were selected for the testing. Regarding orifice size, K17 sprinklers were determined to be the most popular model compared to K22-K25 sprinklers. In addition, given their smaller orifice sizes and corresponding smaller droplet sizes, K17 sprinkler performance was assumed to be more biased by discharge interference created by obstructions. Consequently, results of the K17 sprinkler research should, in theory, be applicable to larger K factor sprinklers, such as K22-K25 sprinklers. K17 sprinklers were used for Phases 2 and 3.

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The use of K14 sprinklers was initially discounted given the recent controversy regarding the adequacy of K14 sprinklers to protect rack arrays of Group A plastic beneath a 40-foot ceiling. However, the extensive legacy use of the K14 sprinkler prompted the exploration of its performance in Phase 4. Photo: Wiss, Janney, Elstner Associates, Inc.

performance in Phase 4. A total of 20 ADD tests were performed using similar test scenarios to that of the K17 ESFR sprinkler.

Phase 2 examined K17 sprinkler performance related to the obstructions located in the horizontal plane of the sprinkler. The ADD apparatus was used to determine the performance of the sprinkler in the presence of open web steel truss and bridging member obstructions and to select the testing scenarios relevant for the full-scale testing of the sprinkler. Approximately 22 ADD tests and five full-scale tests were performed with K17 sprinklers.

Phase 3 introduced vertical obstruction types, including 3-inch flat, 6-inch flat, 12-inch flat, 3-inch round, 6-inch round and 1 1/2-inch bridging members. A total of 22 ADD tests were performed using K17 sprinklers to determine which full-scale tests would be the most rigorous. Three full-scale tests were performed.

Phase 4, as previously mentioned, focused on the performance of the K14 sprinkler in configurations similar to those explored in Phase 3. A total of 21 ADD tests were performed to compare the performance of K14 ESFR sprinklers to that of K17 ESFR sprinklers. One full-scale test using K17 sprinklers was performed.

The Results

The findings of the project are as follows:

• The obstruction created by an open web steel truss 22 inches to 36 inches in depth, located a minimum of 6 inches horizontally from an ESFR sprinkler, will not significantly decrease sprinkler performance.

• The obstruction created by a bridging member or other obstruction 1 1/2 inches by 1 1/2 inches in size or less, located a minimum of 12 inches directly below an ESFR sprinkler, will not significantly decrease sprinkler performance. This also applies to a bridging member attached to an open web steel truss.

• The obstruction created by a flat or round obstruction less than or equal to 12 inches in width, located a minimum of 6 inches horizontally from an ESFR sprinkler, will not significantly decrease sprinkler performance.

• The obstruction created by a flat or round obstruction less than or equal to 24 inches in width, located a minimum of 12 inches horizontally from an ESFR sprinkler (K14 or K17), will not significantly decrease sprinkler performance.

The findings of the research project were used as the basis for code changes to NFPA 13. These changes were approved through the NFPA code development cycle for publication in the 2022 edition of NFPA 13. Note the code changes are slightly more conservative than the findings of the research.

In addition, an ESFR Obstruction Tool was developed and is located within the project's final report, available at https://bit.ly/3ykn4xE. ●

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