Impact of Obstructions on Sprinkler Performance

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Automatic water-based sprinkler systems have successfully been used to protect properties for over 100 years and are considered a fundamental aspect of building fire protection strategies, especially in commercial occupancies. According to the NFPA US Experience with Sprinklers Study [1], sprinklers operated in 92% of the fires where sprinklers were present and the fire was large enough to activate them. Sprinklers were effective at controlling the fire in 96% of fires in which they operated.

Despite their widespread success, sprinklers operated ineffectively in approximately four-percent of fires in protected occupancies in 2017 [1]. Among the incidents where sprinklers operated ineffectively, water did not reach the fire in 51% of these fires and the actual delivered density was inadequate in 30% of these fires [1]. While there are numerous factors that can contribute to inadequate sprinkler performance, obstructions can play a significant role in preventing sufficient water from reaching the hazard, disrupting spray pattern development, delaying activation time, enabling sprinkler skipping, or preventing water from reaching the hazard.

As the use and installation of automatic sprinkler systems continues to grow around the world, it is important to ensure that our design strategies minimize the potential impacts of obstructions on sprinkler performance. Several variables including the type of obstruction (continuous or non-continuous), size of obstruction, distance of the obstruction from the deflector, sprinkler type (e.g. ESFR, spray sprinkler, etc.), K-Factor, and operating pressure can have a significant impact on a sprinkler’s ability to control a fire. NFPA 13, Standard for Installation of Sprinkler Systems and FM Data Sheet 2-0, Installation Guidelines for Automatic Sprinklers have detailed sets of criteria regarding obstructions to sprinkler discharge, however, the existing rules do not sufficiently address all the variables mentioned herein.

Impact

Obstructions (continuous or non-continuous) can be classified as single or multiple objects at or below the level of sprinkler deflectors that affect the discharge patterns of one or more adjacent sprinklers [2]. Anything from architectural features to standard building elements, like ductwork, piping, bar joists, beams, columns, elevated walkways or other objects, can serve as an obstruction to sprinkler discharge under certain scenarios. The tolerance for an obstruction’s interruption to sprinkler performance can vary, however, it is generally dependent on the severity of the hazard and the performance objectives of the sprinkler system.
The impact of various obstructions on sprinkler performance can be classified into two key categories: 1) Impact on activation and 2) Impact on water discharge and distribution.

**Impact on Activation**

To effectively control or suppress a fire and minimize loss, it is critical for sprinklers to activate quickly, particularly in high challenge storage scenarios. But a sprinkler can only be effective if the heat is able to reach and activate the sprinkler in a timely manner and the appropriate quantity of water is able to reach the fuel. Since a sprinkler’s effectiveness is time and density dependent, if an obstruction delays the rate of heat transfer to the sprinkler, the fire will be able to grow beyond the anticipated heat release rate, presenting challenges for the sprinkler to control the fire as designed [7].

**Impact on Water Discharge and Distribution**

The type, size and location of an obstruction in relation to a sprinkler will significantly influence its impact on water discharge and distribution. Even though the existing guidelines are largely anecdotal, there is extensive guidance in current codes and standards regarding the recommended placement of sprinklers to minimize the impedance of nearby obstructions [2]. In addition to the obstruction properties, the characteristics of the sprinkler and its interaction with specific obstructions will have a strong influence on performance.

Interruptions to spray pattern development is another variable that can impact water discharge and distribution. While the spray pattern of many sprinklers may be similar, they all have unique spray patterns that are influenced by the sprinkler type and pressure [7]. The tolerance for an obstruction’s impact will also vary based on the hazard being protected, among other variables.

**Research and Testing**

Despite the long-standing design guidance in NFPA 13 that aims to minimize the impact of obstructions on sprinkler performance, there are still fundamental gaps in understanding of the challenges presented by obstructions. This is largely due to the lack of quantitative assessments on obstructions’ impact on sprinkler activation and control. The Fire Protection Research Foundation has been addressing this issue through several research programs over the last few years, which focus on quantifiable evaluations of the impact of obstructions on early suppression fast response (ESFR) and spray sprinklers, along with an analysis of elevated walkway’s impact on sprinkler protection in storage occupancies.

These projects analyze how various obstructions can impede or block a sprinkler’s spray and influence the spray pattern development, activation time, and overall sprinkler performance and delivery of water to the hazard. The goal is to determine what obstruction/sprinkler configurations have a negligible, impactful, or questionable impact.

**Impact of Obstructions on ESFR Sprinklers (Phases I-IV)**

The unique spray pattern and discharge characteristics of ESFR sprinklers raised concerns about the impact obstructions may have on their performance. Since ESFR sprinklers are typically installed in high challenge and high hazard warehouses, it is critical for ESFR sprinklers to be able to meet their performance objectives. Phases I - III of this project 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 utilizing K17 ESFR sprinklers and the
results are published through the Foundation. From the full-scale fire tests that were conducted, the following conclusions were made [3,4,5]:

- Considering the results from all tests, 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.

This project is currently in Phase IV, which is now further evaluating the impact of obstructions on ESFR sprinklers through additional full-scale testing and ADD testing of K14 sprinklers.

**Impact of Obstructions on Spray Sprinklers – Phase I**

While the obstruction requirements in NFPA 13 are more relaxed for spray sprinklers in comparison to ESFR sprinklers, there is still a significant lack of understanding of how spray sprinklers interact with obstructions and the resultant impact on performance. This Phase I study evaluated the technical substantiation of the existing obstruction requirements, performed a gap analysis and developed a comprehensive research plan to address the knowledge gaps and enhance the scientific basis of obstruction guidance [7].

**Impact of Elevated Walkways in Storage on Sprinkler Protection – Phase I**

Warehouses have historically been difficult to protect, but the overall size and height of warehouses continues to grow which poses more challenging fire scenarios. As a result, elevated, grated walkways are becoming extremely prevalent in modern warehouses. However, the presence of elevated walkways can influence sprinkler performance by the grate disrupting the spray, impacting the plume dynamics, delaying sprinkler activation, and potentially preventing pre-wetting of adjacent storage racks. How the characteristics of the walkways influence sprinkler performance is not well understood. Since the available guidance and literature on the impact of elevated walkways in storage is somewhat limited, the preliminary results of this study have identified critical knowledge gaps and a future research plan to enhance our understanding of the interaction between elevated walkways and acceptable sprinkler performance [6].

**Future Work**

Two Research Foundation studies – “Impact of Obstructions on Spray Sprinklers” and “Impact of Elevated Walkways in Storage on Sprinkler Protection” – are expected to continue to Phase II to address a number of identified knowledge gaps. This future work will aim to develop a fundamental understanding of the dynamics between sprinklers and obstructions through spatially resolved spray characterization, CFD modelling, cold flow testing and full-scale fire tests. The knowledge gaps to be filled through these next phases of work, include [6,7]:

- How variations in sprinkler pressure and k-factor influence spray development
- How multiple, small, adjacent objects can obstruct sprinkler sprays when placed near each other.
- How obstructions impact blockage ratios and shadowing
- How various obstruction scenarios impact sprinkler performance, on a scale of significance
- How obstructions can influence activation times and the potential for sprinkler skipping
- How the porosity of the elevated walkway impacts plume development, sprinkler activation, sprinkler spray development and pre-wetting of adjacent combustibles;
- How the grate geometry impacts plume development, sprinkler activation, spray development and water delivery
• How floor coverings can impact sprinkler activation times, spray coverage, and pre-wetting

Every building will be unique, obstruction scenarios will be diverse, hazards will evolve over the lifecycle of the building, and the fire location will be unpredictable. Our on-going research aims to enhance our understanding of the impact of obstructions on sprinkler performance through scientific quantitative assessments to minimize future inefficiencies.

References