UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

July 19, 2002

NRC INFORMATION NOTICE 2002-24: POTENTIAL PROBLEMS WITH HEAT COLLECTORS ON FIRE PROTECTION SPRINKLERS

Addressees

All holders of licenses for nuclear power, research, and tests reactors and fuel cycle facilities.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to alert licensees to potential problems with using heat collectors on sprinklers and fire detectors installed to satisfy NRC fire protection requirements. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate. However, suggestions contained in the IN are not NRC requirements; therefore, no specific action or written response is required.

Background

NRC fire protection engineers and inspectors have recently raised technical concerns regarding the adequacy of sprinklers that rely on metal plates, commonly referred to as “heat collectors,” to activate (see Figure 1 in the attachment). When convective heat energy rises above the fire plume, it terminates its vertical movement at the ceiling and flows past the sprinkler’s heat-sensitive element. This flow of heat across the ceiling is called the “ceiling jet.” The ceiling directs the convective heat energy horizontally towards the sprinklers nearest the fire. If the sprinkler’s heat-sensitive element is a fusible link, the heat melts the link, releasing water to control the fire. If the sprinkler’s heat-sensitive element is a glass bulb, the heat expands the liquid in the glass bulb until the bulb breaks, releasing water to control the fire.

Heat collectors were intended to reduce the time a fire takes to activate sprinklers located too far below the ceiling. When sprinklers are too far below the ceiling, most of the heat energy rises past the sprinklers and heat collectors and the sprinklers are not activated. Locating the sprinkler close to the ceiling ensures that the sprinkler will be in the hot gas layer, minimizing activation time and enabling the sprinkler to provide a fully developed water spray pattern to control the fire. In addition, the water from the sprinkler cools the upper gas layer (preventing flashover conditions) and cools the structural steel supports of the compartment boundaries (preventing structural collapse).

In the late 1970s and early 1980s, some sprinkler system designers and fire protection engineers supported the opinion that sprinklers could be placed far below the ceiling if heat collectors were installed above them to help activate them during a fire. They reasoned that

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heat from the fire plume can create temperatures or draft conditions that cause water droplets to evaporate before penetrating and cooling the plume and that large clearances between sprinklers and floor-level combustibles could aggravate the problem of ensuring that the correct sprinkler water density is available from sprinklers. Therefore, they installed heat collectors so that sprinklers could be closer to the combustibles at floor level.

Other sprinkler system designers and engineers thought that ceilings were too congested with cable trays, conduits, piping, ductwork, etc., and that sprinklers could be mounted below these ceiling-level obstructions to develop adequate spray patterns. The 1999 edition of National Fire Protection Association (NFPA) 13, “Standard for the Installation of Sprinkler Systems,” provides requirements for the installation of sprinklers under obstructed ceilings. NFPA 13, Section 5-6.4.1.1, states that “under unobstructed construction, the distance between the sprinkler deflector and the ceiling shall be a minimum of 1 in. (25.4 mm) and a maximum of 12 in. (305 mm).” In certain cases NFPA 13 allows sprinklers to be placed as far as 22 inches below an obstructed construction. NFPA 13 also requires sprinklers to be installed below fixed obstructions and to provide full ceiling-level sprinkler coverage[1]. These NFPA 13 requirements appear to be consistent with the requirements of NFPA 13 from the early 1980s.

Generic Letter (GL) 86-10, “Implementation of Fire Protection Requirements,” provides guidance on sprinkler location. Section 3.4.3, “Sprinkler Location,” and Section 3.4.5, “Sprinkler Head Location,” state that sprinkler system designs should meet NFPA 13 and be located at the ceiling. The GL also states that “in order to achieve complete area wide coverage, sprinklers should be located at the ceiling, with additional sprinklers provided below significant obstructions such as wide HVAC ducts and ‘shielded’ or solid bottom stacked cable trays. To the extent that an existing or proposed sprinkler system deviates from this concept, the design would have to be justified by a fire hazards analysis.” GL 86-10 provides no heat collector guidance.

NFPA 13 contains no guidance or requirements regarding the installation of heat collectors in lieu of a ceiling. To understand the origins of the heat collector concept, the NRC staff examined previous editions of NFPA 13. The staff discovered that NFPA 13 has never permitted, required, or taken a formal position on the installation of heat collectors installed above sprinklers in lieu of locating the sprinklers close to the ceiling. The term “heat collector” was first used in the NFPA 13 standard up to the 1963 edition and was listed in the index of NFPA 13 up to the 1974 edition. The term first appeared in the NFPA 13 section on “Guards & Shields” for protecting sprinklers. The staff discovered no references to heat collectors in any editions of the NFPA 13 section that address the distance of sprinklers from the ceiling. “Heat collectors” was changed to “baffles” in the 1963 edition during the NFPA document revision. NFPA 13 was completely revised again in 1973, and “baffles” became “shields.”

NFPA 13 makes it clear that there are acceptable uses of shields. Shields are very similar in design to heat collectors. Shields are metal plates installed over sprinklers in midair in fire areas where full ceiling-level sprinkler protection is also provided. Shields function solely to protect the midair sprinklers from “cold-soldering.” The cold-solder effect occurs when an

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[1]NFPA 13, Section 5-5.5.3.1, 1999 edition, states that “sprinklers shall be installed under fixed obstructions over 4 ft (1.2 m) wide such as ducts, decks, open grate flooring, cutting tables, and overhead doors.”

operating sprinkler (usually at the ceiling) wets midair sprinklers, delaying or preventing their activation. The wetting prevents the midair sprinklers from fusing (opening) to release water. Sections 6-4 and 7-4 of NFPA 231C, "Rack Storage of Materials," state that "water shields shall be provided directly above in-rack sprinklers, or listed sprinklers equipped with water shields shall be used where there is more then one level, if not shielded by horizontal barriers." NFPA 13 also provides guidance on the use of shields to prevent mechanical injury to sprinklers and protect sprinklers under open gratings.

The first tests of heat collectors were apparently the tests conducted for the U.S. Atomic Energy Commission (AEC, the predecessor to the NRC) by Union Carbide at the Oak Ridge Y-12 Plant and documented in a 1973 report. Union Carbide tested sprinklers with and without canopies (i.e. heat collectors) for response above kerosene fires. In the spring 1989 *Sprinkler Quarterly*, Russell P. Fleming contended that heat collector testing at the Oak Ridge Y-12 plant was flawed. Fleming concluded that the test scenario placed the heat collector and standard response sprinkler 3 feet above the kerosene fire, so that the sprinkler mainly activated by radiant heating. In a more realistic fire scenario the sprinkler would be activated primarily by convective heating.

Similar findings were reported in a January 1990 report, "A Study of the Utility of Heat Collectors in Reducing the Response Time of Automatic Fire Sprinklers Located in Production Modules of Building 707," prepared for the U.S. Department of Energy Rocky Flats Plant by Hughes Associates, Inc. (HAI). HAI conducted small-scale and large-scale testing for the Rocky Flats Plant to determine if heat collectors directed enough of the convective heat of the fire plume past sprinklers to activate them. HAI also studied the effect of using a quick-response sprinkler in lieu of a standard-response sprinkler with a heat collector. The results of the HAI tests for the Rocky Flats Plant are summarized below:

- Heat collectors with the edges turned down around the side produced a dead air space and the sprinklers had longer response times than sprinklers with a flat heat collector[2] (see Figure 2 in the attachment).

- The heat collector must be in the plume to be effective. If the centerline of the fire is more than 1 to 2 feet from the edge of a flat heat collector, a standard-response sprinkler may take longer to respond, regardless of its thermal sensitivity.

- If a fire is midway between two sprinklers, the sprinklers may not respond at all (regardless of the size of the heat collector) because the sprinklers are not exposed to the convective heat flow of the ceiling jet.

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[2]This also applies to fire detectors with heat collectors. Dead air spaces under heat collectors can prevent fire detectors from activating during the incipient stages of a fire.

- Quick-response sprinklers activate more quickly than standard-response sprinklers only if the fire was directly underneath the heat collector.[3]

Description of Circumstances

The primary objective of the fire protection programs at U.S. nuclear power plants (NPPs) is to minimize the probability and consequences of a fire in accordance with General Design Criterion 3 of 10 CFR Part 50, Appendix A. To meet these objectives, the fire protection programs at NPPs must provide reasonable assurance, through defense-in-depth, that a fire will not prevent the performance of necessary safe-shutdown functions and that radioactive releases to the environment will be minimized. Part 10 to the *Code of Federal Regulations* (CFR), Section 50.48, "Fire protection," and 10 CFR Part 50, Appendix R, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979," require that automatic fire suppression systems be installed in certain fire areas to protect separated or redundant trains of safe-shutdown equipment and circuits or to protect against a fire hazard.

NRC is concerned about the adequacy of sprinklers with heat collectors because NRC inspectors have found a lack of technical documentation, tests, or calculations to support the installation of sprinkler systems with heat collectors in fire areas. In addition, NRC inspectors have found that some licensees have not performed an engineering evaluation to justify the installation of heat collectors at their facilities.

NRC plant walkdowns have identified other heat collector concerns. One concern is the location of sprinklers with heat collectors located below the primary combustible source (i.e., cables installed in cable trays). In this configuration, if a cable fire occurred, the sprinklers would not activate. Other concerns relate to the configuration and orientation of heat collectors over sprinklers. Inspectors have discovered some heat collectors tilted at an angle over the sprinklers or even installed sideways. The technical concern is that tilted or vertical heat collectors over sprinklers could obstruct or deflect the spray pattern of the sprinklers (provided the sprinklers activate), preventing the sprinkler from effectively controlling the fire. Figure 3 of the attachment shows how an improperly placed heat collector can obstruct the sprinkler spray pattern.

With respect to the NFPA code requirements, the heat collector concerns raised by NRC inspectors usually involve one of two issues:

- In fire areas where the licensee commits to NFPA 13, the distance of the sprinkler from the ceiling does not comply with the NFPA 13 spacing and location requirements (i.e., a sprinkler with a heat collector below cables installed in cable trays or a midair sprinkler for transient fire control).

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[3]The thermal sensitivity of a sprinkler operating element is called the "response time index" (RTI). The RTI provides an indication of how fast the element can absorb enough heat from its surroundings to activate the sprinkler. Standard-response sprinklers have higher RTIs than quick-response sprinklers. The lower the RTI, the faster the sprinkler activates. However, even a quick-response sprinkler with a low RTI will not activate unless it is immersed in the ceiling jet.

- Water spray systems have been installed under heat collectors in some fire areas where the licensee designed the system to the requirements of NFPA 15, “Water-Spray Fixed Systems For Fire Protection.” In accordance with NFPA 15, water spray systems require directional water spray nozzles, which are open nozzles. Open nozzles do not have a heat-sensitive element (such as a fusible link). This allows water to flow from all nozzles at the same time to protect the hazard once the detection system receives an alarm and trips the deluge valve. Since water spray systems typically are open nozzles (with no heat-sensitive element), there are no NFPA 15 requirements for nozzles to be located within a certain distance from a ceiling or overhead beam. This is based on the fact that the principal design consideration for a water spray system, is the spray pattern the open nozzles will develop in protecting the hazard.

  To prevent inadvertent actuation of water spray systems onto components such as sensitive electrical components, some licensees have installed automatic directional water spray nozzles, which are closed nozzles. Closed nozzles can only operate when the heat-sensitive element is activated. So an automatic directional water spray nozzle operates on the same principle as an automatic sprinkler. They both have heat-sensitive elements which rely on the heat of a fire to fuse (open), to release water on to the fire. As previously discussed, the closed nozzle and automatic sprinkler both require proper placement in the ceiling jet so that the heat-sensitive element is exposed to the convective flow of heat from a fire.

  Although NFPA 15 does not require nozzles to be located within a certain distance from the ceiling or overhead beam, the 2001 Edition of NFPA 15, Section 6.2.1.2 does state that “automatic nozzles shall be permitted when positioned and located so as to provide satisfactory performance with respect to activation time and distribution.” Based on the operation of the heat-sensitive element, the same concerns with respect to automatic sprinkler placement and response time are also applicable for automatic directional water spray nozzles.

The ceiling is widely recognized as a fundamental means of directing heat to the sprinklers located closest to the fire. The use of sprinklers with heat collectors installed far below the ceiling has not been demonstrated to be effective and may impair sprinkler system response. Sprinklers are also used to prevent flashover and the collapse of structural steel. Furthermore, fire areas with large amounts of combustibles above the sprinkler, may not be adequately protected in accordance with General Design Criterion 3.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Attachments:
1. Figures 1, 2, and 3
2. List of Recently Issued NRC Information Notices
3. List of Recently Issued NMSS Information Notices

References:

1. Fleming, Russell P., “High-On Sprinklers,” Part II, *Sprinkler Quarterly*, Spring 1989, pp 21.

2. McCormick, J.W., and DeMonbrun, J.R., “Experiments With Sprinkler Head Canopies for Fire Protection, Oak Ridge Y-12 Plant,” U.S. Atomic Energy Commission Y-JA-96 July 2, 1973.

3. NFPA 13, “Standard for the Installation of Sprinkler Systems,” National Fire Protection Association, Quincy, Massachusetts.

4. NFPA 15, “Water-Spray Fixed Systems for Fire Protection,” National Fire Protection Association, Quincy, Massachusetts.

5. NFPA 231C, “Rack Storage of Materials,” 1998 edition, National Fire Protection Association, Quincy, Massachusetts.

6. Shanley, J. H. , and Budnick, E.K., “A Study of the Utility of Heat Collectors in Reducing the Response Time of Automatic Fire Sprinklers located in Production Modules of Building 707,” RFP-4874, Hughes Associates, Inc., January 1990.

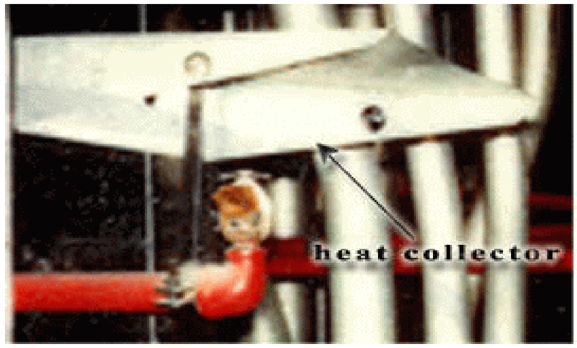

Figure 1 An upright sprinkler with a heat collector

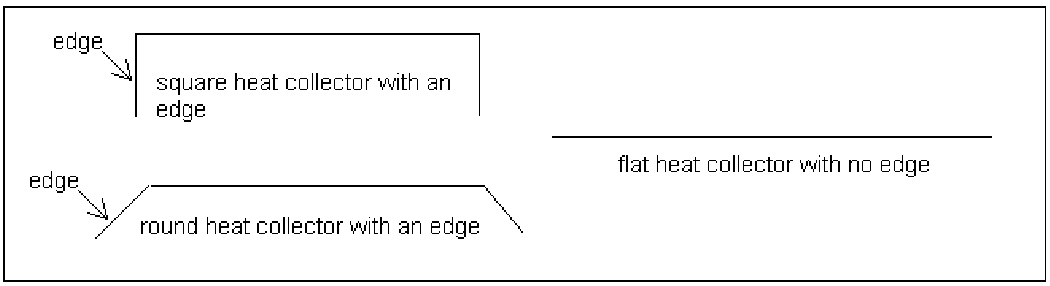

Figure 2 Heat collector with an edge and without an edge

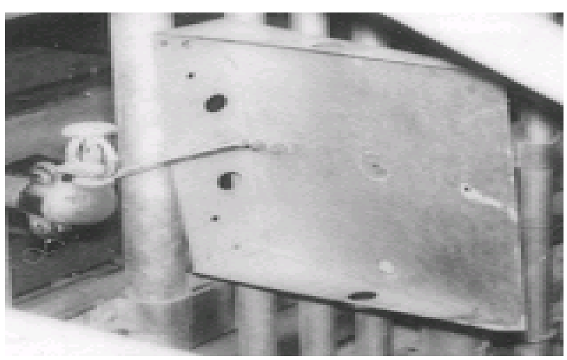

Figure 3 A heat collector obstructing sprinkler spray pattern