INSTALLATION RULES FOR SUPPRESSION MODE AUTOMATIC SPRINKLERS

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1.0 SCOPE

This standard contains the installation requirements for suppression mode sprinklers, which include:

- K14.0(K200), K16.8(K240), K22.4(K314) and K25.2(K360) pendent suppression mode sprinklers
- K14.0(K200) upright suppression mode sprinklers

These sprinklers are intended for use in protecting solid-piled, palletized, and open-frame rack storage, as well as other storage configurations for which they have been specifically evaluated. They are not intended for use in protection of manufacturing or other non-storage occupancies.

It is easy to assume that suppression mode sprinklers which can suppress a high-challenge storage fire will have no problem with ‘‘less hazardous’’ occupancies. But such a conclusion ignores the fact that suppression mode sprinklers were designed to achieve suppression of a very specific and limited range of fire scenarios, and have only been tested in those scenarios. Not only are suppression mode sprinklers not an economically practical means of protection for non-storage occupancies, there are many occupancies which do not lend themselves to suppression mode protection and simply cannot be properly protected by suppression mode sprinklers. Specific examples include flammable liquid operations, occupancies with shielded combustibles, etc.

Suppression mode sprinkler technology offers a number of attractive advantages over the older control-mode sprinkler technology. Chief among these is the possible elimination of the requirement for in-rack sprinklers in rack storage areas. Achieving these advantages requires a sprinkler technology vastly different from previous technologies, a technology, however, which has much less tolerance for deficiencies in design and installation than older technologies. If suppression mode sprinklers fail to suppress a fire, the consequences can be severe. Thus, this new technology demands a far higher level of attention to detail in sprinkler design, and – perhaps even more importantly – installation.

Properly functional suppression mode sprinkler installations require that the unique requirements of this technology be compatible with the facility they will protect. As a result, retrofitting of suppression mode sprinklers in existing facilities, if possible at all, can be a costly and frustrating exercise.

For new facilities, suppression mode sprinkler requirements must be incorporated into the design process from the earliest stages of planning. If the building design is completed before sprinkler design is begun, it can result in costly changes and delays. If construction starts before the sprinkler design is done, it is entirely possible that use of suppression mode sprinklers will be impossible.

1.1 Changes

In addition to major organizational changes, this standard includes the following technical changes:

- Discussion of suppression mode sprinklers other than K14.0 (K200) pendent suppression mode sprinklers is incorporated. (K16.8 (K240), K22.4(K314) and K25.2 (K360) pendent suppression mode and K14.0 (K200) upright suppression mode).
- Individual isolated obstructions are no longer permitted.
- Discussion of obstructions has been significantly expanded.
- Construction types are addressed in terms of performance requirements, not definitions.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

The words *requirements*, *must* and *shall* in this data sheet mean that no deviation from installation requirements is permitted. Table 1 summarizes the basic suppression mode sprinkler installation requirements.

Table 1. Summary of Suppression Mode Sprinkler Installation Requirements

Type of storage	Refer to occupancy data sheets for storage arrangements that can be protected.
Commodity	Refer to occupancy data sheets for commodities that can be protected.
Maximum storage height, ft (m)	Refer to occupancy data sheets.
Maximum height of building, ft (m)	Refer to occupancy data sheets.
Roof construction	Install suppression mode sprinklers in every bay or channel formed by solid structural members at the ceiling, except when the solid structural members extend no more than 12 in. (305 mm) below the ceiling, and sprinklers are located below the bottom of the members. • Automatic roof vents require high-temperature rated, standard response operating mechanism. Melt-out roof vents not permitted.(See section 2.2.4). • No exposed expanded plastic construction.
Sprinklers	**Type:** FM Approved (see Appendix A for definition) K14.0 (K200), K16.8 (K240), K22.4 (K314), K25.2 (K360) pendent and K14.0 (K200) upright suppression mode sprinklers with ordinary and intermediate temperature. **Location:** • K14.0 (K200) upright and pendent, and K16.8 (K240) Pendent: Centerline of thermal sensing element maximum of 13 in. (330 mm) and minimum of 4 in. (102 mm) below the ceiling, or from the deflector to the ceiling a maximum of 14 in. (356 mm) and a minimum of 5 in. (121 mm). • K22.4 (K314) and K25.2 (K360) Pendent: Centerline of thermal sensing element maximum of 18 in. (457 mm) and minimum of 4 in. (102 mm) below the ceiling.
Sprinkler System	**Type:** Wet only **Hydraulic Design:** Most remote 12 sprinklers flowing 4 sprinklers on 3 branch lines, with design discharge pressure as specified by occupancy data sheets. **Spacing:** Minimum 8 ft (2.4 m) and maximum 12 ft (3.7 m) between sprinklers or branch lines for buildings up to 30 ft (9.14 m) high. For buildings higher than 30 ft (9.14 m) up to 45 ft (12.2 m), the maximum allowable spacing is 10 ft (3.05 m). The maximum area to be covered by a sprinkler is 100 ft^2 (9.3 m^2) and the minimum is 64 ft^2 (5.8 m^2) (see section 2.4.7)
Hose streams	Refer to occupancy data sheets.
Water supply duration	Refer to occupancy data sheets.

2.2 Construction and Location

Prompt sprinkler operation and unobstructed sprinkler discharge are critical to effective suppression mode sprinkler protection. Construction features have a significant effect on both of these critical factors.

In all cases, the installation must meet the minimum distance requirements between the sprinkler and the ceiling above as specified in section 2.4.4 and the obstruction requirements of section 2.4.5.

2.2.1 Roof Construction

2.2.1.1 Install suppression mode sprinklers in every bay or channel formed by solid structural members at the roof or ceiling.

- Examples of construction types in which this is typically practical include smooth roof or floor decks supported directly on beams, girders or trusses, or continuous smooth bays formed by wood, concrete or steel beams.
- Examples of construction types in which this is typically not practical due to the requirement for sprinklers in every bay or channel, and/or obstruction requirements include concrete tees, wood truss-joists, and closely spaced concrete beams.

Exception: Sprinklers are not required in every bay or channel and spacing may be based on the maximum allowable spacing as determined by the building height when the solid structural members extend no more than 12 in. (305 mm) below the ceiling and sprinklers are located below the bottom of the members.

Examples include metal buildings with z-purlins less than 12 in. (305 mm) deep and concrete tee construction less than 12 in. (305 mm) deep.

Install suppression mode sprinklers based on the maximum allowable spacing as determined by the building height where roofs or ceilings are supported by members whose webs are a minimum of 70% open, or where there is a smooth monolithic ceiling having suitable uplift resistance as described in section 2.2.5.

Examples include roofs/ceilings supported by bar joists and open-web steel trusses and continuous suspended ceilings.

2.2.2 Ceiling Slope

2.2.2.1 Do not install suppression mode sprinklers beneath roofs or ceilings where the slope exceeds 2 in./ft (167 mm/m, 9.5°).

Where roof/ceiling slope is in excess of 2 in./ft (167 mm/m, 9.5°), a sub-ceiling with proper slope may be installed above the storage with sprinklers installed below. Provide sprinkler protection in the concealed space if the contents or the construction in the concealed space or ceiling is combustible. (Refer to Data Sheet 1-12, *Ceilings*.)

2.2.3 Steel Protection

When suppression mode sprinkler systems are installed in accordance with this data sheet, fire protection is not needed for roof and column steel.

2.2.4 Heat and Smoke Venting

If a fire starts beneath an automatic heat/smoke vent and that vent operates before sprinklers do, the venting could result in a critical delay in sprinkler operation.

Plastic skylights that are not designed as heat/smoke vents do not create this problem.

2.2.4.1 Do not install suppression mode sprinklers in buildings with automatic heat/smoke vents unless the vents use a high temperature-rated standard response operating mechanism.

2.2.4.2 Do not install suppression mode sprinklers in buildings with melt-out (drop-out) type vents.

2.2.5 Suspended Ceilings

When the ceiling height is higher than that permitted in the applicable occupancy standard, suppression mode sprinklers can be installed beneath a suspended ceiling to reduce the ceiling height to an acceptable level.

Suspended ceilings should extend to vertical floor-to-ceiling walls or partitions. If not, eliminate storage between the edge of the ceiling and the nearest sprinklers.

Design suspended ceilings to withstand fire plume uplift velocity pressures of at least 3 lb/ft^2 (14.4 kg/m^2). Suitable ceiling materials include ⅜ in. (10 mm) plywood or gypsum board, corrugated or sheet steel, and fiberglass or mineral tile. Fasten tiles securely to the supporting framework. Hold-down clips used to anchor ceiling tiles will suffice for securing the mineral tile. If the ceiling is hung from the existing roof framework, ensure the roof can withstand the additional dead load.

2.2.6 Roof and Ceiling-Level Ventilation

Ventilation (both natural and powered) at the ceiling level can create problems similar to those caused by automatic heat and smoke vents. If a fire starts beneath a natural-draft vent, the vent can capture the fire plume , significantly delaying sprinkler operation. If air velocity at a sprinkler caused by a powered vent or air supply is too high, it can also result in a critical delay in sprinkler.

- Examples of powered ventilation include exhaust fans, air conditioning/refrigeration supply and return vents, and grated return air inlets to roof-mounted mechanical equipment penthouses.
- Examples of natural ventilation include turbine vents, vent stacks, and ridge vents.

2.2.6.1 Coordinate the location of sprinklers and the design of powered heating, ventilation and air conditioning for buildings protected by suppression mode sprinklers so that the air velocity at sprinklers does not exceed 5 ft/sec (1.52 m/sec).

2.2.6.2 If it is not possible to meet 2.2.6.1, chose one of the following options to ensure proper operation of suppression mode sprinklers in buildings with ceiling-level ventilation:

a) Sprinklers Beneath Vent Openings

Install suppression mode sprinklers of the same type used elsewhere in the building centered in vent openings having a maximum dimension of 4.5 ft (1.37 m). This option does not apply to storage of commodities greater in hazard than cartoned unexpanded plastic, such as uncartoned plastic, aerosols or rolled tissue in buildings higher than 30 ft (9.14 m).

b) Subceiling

Install a subceiling under the vent and install suppression mode sprinklers below the ceiling. Locate and size the subceiling so that the air velocity at sprinklers around the subceiling does not exceed 5 ft/sec (1.52 m/sec). Maintaining air velocities at the required level may result in a large subceiling and the required vertical distances from the ceiling to the subceiling may be large. Design the subceiling to meet the requirements of section 2.2.5.

c) Heat/Flame Detection

Install FM Approved line-type detection or flame detection designed to shut fans down in powered ventilation systems or to close dampers in natural ventilation systems upon actuation. As the goal is to shut down fans before they can delay operation of the first sprinklers, shutting down fans or closing dampers by sensing water flow is not an option. Ordinary smoke detectors installed in ducts also respond too slowly to be effective for this application.

Line-type detection will typically be the most cost-effective choice in most cases. The detector array should consist of parallel lines located under the vent opening within 6 in. (152 mm) of the ceiling or vent plane. Space the parallel lines no more than 15 in. (381 mm) apart to ensure that the hot gases are intercepted. The temperature set point should be 165°F (74°C).

Flame detection to stop fans or close dampers may be provided by four FM Approved flame detectors equally spaced on a 10 ft (3.05 m) diameter circle around the vent opening. Install the detectors a minimum of 5 ft (1.52 m) above the top of the storage. A FM Approved detector having an effective viewing cone of 90° or greater is recommended. Follow the manufacturer's installation guidelines.

2.2.6.3 Ridge Vents. The only practical way to protect ridge vents and other similar vents that remain open to the atmosphere is by providing sprinklers beneath them at roof level for vents no wider than 4.5 ft (1.37 m), or by installing a subceiling with suppression mode sprinklers below as described above for wider vents.

2.2.7 Draft Curtains

Draft curtains are often required by local codes, but if not properly arranged, these curtains can interfere with the proper distribution of sprinkler discharge.

Draft curtains also are needed in some cases to separate areas protected by suppression mode sprinklers from areas protected by control-mode sprinklers. If a fire occurs in an area protected by control-mode sprinklers near the boundary with suppression mode sprinklers, this can result in operation of suppression mode sprinklers away from the fire. Because suppression mode sprinklers discharge a relatively large amount of water, they may divert water from the control-mode sprinklers.

2.2.7.1 When draft curtains are required, center them between sprinklers or sprinkler branch lines. If they are not centered, provide additional sprinklers such that sprinklers on either side of the draft curtain are no farther from the curtain than one-half the allowable maximum sprinkler spacing for the building height. If suppression mode sprinklers protect the areas on both sides of the draft curtain, there is no need to maintain a clear aisle beneath the draft curtain.

2.2.7.2 Install draft curtains to separate areas protected by suppression mode sprinklers from areas protected by control-mode sprinklers when the two areas have the same ceiling height or when they have different heights and the suppression mode sprinklers are at the higher elevation.

Extend the draft curtain at least 2 ft (0.61 m) below the ceiling. Ensure the draft curtain is noncombustible and fits tightly against the underside of the roof. (Openings created by ribs in metal roof deck are not a concern, but openings created by channels between Z-purlins or other structural members should be filled.) Solid beams, girders or other structural features which meet the above criteria are equivalent to draft curtains.

Draft curtains must be centered over clear aisles at least 4 ft (1.2 m) wide.

2.3 Occupancy

2.3.1 Storage Clearance

Maintain storage a minimum of 36 in. (915 mm) below sprinkler deflectors.

2.3.2 Mezzanines, Walkways and Conveyors

Mezzanines, walkways and conveyors are often installed in warehouses protected by suppression mode sprinklers at the roof. Depending on the type, configuration and use, they can prevent water discharge from sprinklers reaching and suppressing a fire and may require installing additional sprinklers.

2.3.2.1 Solid Mezzanines

To prevent simultaneous operation of suppression mode sprinklers beneath and above solid mezzanines and to allow the water demand for sprinklers under the mezzanine to be independent of the water demand for sprinklers above, either provide a draft curtain around the perimeter of the mezzanine or keep all storage underneath the mezzanine inside the sprinklers located nearest the perimeter of the mezzanine.

For mezzanines extending no more than 15 ft (4.6 m) above floor level, install suppression mode sprinklers designed to supply four sprinklers at the pressure required for the type of sprinkler used, or quick response sprinklers designed for the hazard involved.

For solid mezzanines extending more than 15 ft (4.6 m) above floor level, install suppression mode sprinklers using the design criteria required for the storage height and type of sprinkler used.

Control-mode sprinklers designed for the hazard involved may be used below a mezzanine more than 15 ft (4.6 m) high only if a draft curtain is provided at the perimeter.

2.3.2.2 Grated Mezzanines

In order to be considered grated, the grating of a mezzanine must be least 70% open. If the grating is less than 70% open, then make the mezzanine solid (in order to allow sprinklers underneath it to operate promptly) and protect it as a solid mezzanine according to section 2.3.2.1.

If storage exists either above or below a grated mezzanine, but not both above and below, no additional sprinklers are needed under the mezzanine.

If storage or storage structures above and below grated mezzanines are arranged to provide aisles that are vertically aligned above and below, treat the aisle portions of the mezzanines the same as walkways. (See section 2.3.2.3)

If storage or storage structures are not vertically aligned above and below the mezzanine, regardless of openings in the grating, make mezzanine solid and protect it as a solid mezzanine according to section 2.3.2.1.

2.3.2.3 Walkways

Walkways are located between storage structures for material-handling purposes. In order to be considered grated, the grating of a walkway must be least 70% open. Treat grated walkways wider than 10 ft (3 m) as grated mezzanines.

No additional sprinklers are required under single-level grated walkways that are no more than 10 ft (3 m) wide.

For multi-level grated walkways no wider than 10 ft (3 m), provide one line of suppression mode or quick response control-mode sprinklers (K of 8 or greater, ordinary temperature rating). For two-level walkways, install them beneath the lower walkway. For three-level walkways, install them beneath the mid-level walkway. Locate the sprinklers at the center of the walkway, at a maximum horizontal spacing of 10 ft (3 m). Include two of these sprinklers when calculating the ceiling sprinkler water demand. For suppression mode sprinklers, supply these two additional sprinklers at the minimum pressure approved for the type of sprinkler used. For control-mode sprinklers, design the two sprinklers to discharge a minimum of 60 gpm (240 l/min) each.

For solid walkways or walkways less than 70% open, install suppression mode or quick response control-mode sprinklers (K of 8 or greater, ordinary temperature rating) beneath each level of walkway on a maximum horizontal spacing of 10 ft (3 m).

For walkways 6.0 ft (1.83 m) wide or less, install one line of sprinklers located at the center of the walkway. For walkways 6.0 ft (1.83 m) to 10 ft (3.1 m) wide, install two lines of sprinklers located at the faces of the aisles. Include two sprinklers from each line of sprinklers at the hydraulically most remote level in the ceiling sprinkler water demand, regardless of the number of levels installed. (Use two sprinklers for walkways 6.0 ft (1.83 m) wide or less, and four for walkways 6.0 ft (1.83 m) to 10.0 ft (3.05 m) wide.)

Supply additional suppression mode sprinklers at the minimum pressure approved for the type of sprinkler used. For control-mode sprinklers, design the sprinklers to discharge a minimum of 60 gpm (240 l/min) each.

2.3.2.4 Conveyors

Single conveyors are typically located on walkways or mezzanines between storage structures to ease inventory picking. Multiple conveyors are located side-by-side to convey product between storage areas and shipping/receiving areas. In either case, they can obstruct sprinkler discharge and create shielded areas that can prevent fire suppression.

When sprinklers are installed below solid walkways and mezzanines in accordance with this standard, the addition of conveyors on the mezzanines and walkways does not require additional sprinklers.

For grated mezzanines and walkways with belt-type conveyers (or roller-type conveyers less than 50% open), individual conveyers or groups of conveyers wider than 2 ft (0.61 m), sprinklers in addition to those required for the mezzanines or walkways themselves will be required. The only exception to this requirement is where there is no possibility of combustibles being present beneath the conveyers.

Install suppression mode or quick response control-mode sprinklers (K of 8 or greater, ordinary temperature rating) beneath the conveyers on a maximum horizontal spacing of 10 ft (3 m). Include two of these sprinklers in the ceiling sprinkler water demand.

- For suppression mode sprinklers, supply these two additional sprinklers at the minimum pressure approved for the type of sprinkler used.
- For control-mode sprinklers, design the two sprinklers to discharge a minimum of 60 gpm (240 l/min) each.

If sprinklers are installed under both the grated mezzanine and walkways and conveyors, it is only necessary to add a total of two sprinklers to the ceiling demand.

When there are multiple, vertically aligned levels of conveyors that are 50% open or more, add a line of suppression mode sprinklers under the lower conveyor for two levels; add a line under the middle conveyor for three levels.

2.3.2.5 Flue Spaces in Racks

Transverse flues between pallet loads are critical to successful fire suppression by suppression mode sprinklers and must be maintained, regardless of building and storage height. For rack storage higher than 25 ft (7.6 m) Both longitudinal and transverse flues are needed.

In multiple-row rack storage, where pallet loads are butted together in one direction, but there are flues between each row of pallets, a lack of longitudinal flues does not necessarily create a problem for suppression mode protection. The only place where fire can develop vertically is in the flues between rows, and those flues are close together. So long as they are open for the full height of storage, water from properly designed ceiling and/or in-rack sprinklers can reach the fire

The situation where there are open flues at lower levels in racks, that are blocked at higher level does create a severe fire protection challenge as there is a place for fire growth and spread that is shielded from sprinkler discharge. If there are longitudinal flues at any level in the rack, they must be open and clear for the full height of the rack. A common example of this is high rack storage where lift operators cannot see precisely where the pallet loads at the top level, and the longitudinal flue can easily be blocked at that level but remain open at lower levels.

2.4. Protection

2.4.1 Sprinklers

Suppression mode sprinklers are available in a range of orifice sizes and are identified by their K-factor. FM Approved suppression mode sprinklers can have K-factors ranging from a nominal 14(200) to 25(360) and may be available in pendent as well as upright orientations. Each K-factor and orientation has its own specific design criteria and permissible application.

The K14.0 (K200) pendent, being the original suppression mode sprinkler, has the widest array of applications. Do not assume that other suppression mode sprinklers can be used for applications where the K14.0 (K200) pendent sprinkler is permitted.

Refer to the appropriate occupancy standard to determine applicability and design criteria.

2.4.2 Temperature Rating

FM Approved suppression mode sprinklers are available in ordinary and intermediate temperature ratings, and are no more susceptible to premature operation due to high ambient temperatures than other types of sprinklers.

Use ordinary temperature rated suppression mode sprinklers for all applications except those where the temperature at sprinklers can exceed 100°F (38°C).

Select the temperature rating of sprinklers near unit heaters in accordance with Data Sheet 2-8N, *Installation of Sprinkler Systems (NFPA)*.

If the ambient ceiling temperature is continuously or intermittently higher than 100°F (38°C) (as might be the case in a hot climate) use intermediate temperature-rated sprinklers (175°F-225°F, 79°C-107°C).

Do not use suppression mode sprinklers where ambient temperatures can exceed 150°F (66°C).

2.4.3 Sprinkler System Types

Install suppression mode sprinklers in wet systems only. Do not use dry systems or preaction systems, or any system where there can be any delay between operation of the sprinkler and discharge of water. Such delays, even if only a few seconds, can result in a failure to suppress.

Antifreeze systems may be used if the antifreeze solution is approved by FM Approvals. Do not use antifreeze mixtures containing combustible fluids, such as ethylene glycol, propylene glycol, glycerin or alcohol, as testing has shown that they can increase heat release rate at the critical early stage of a fire and prevent suppression. Do not use brine solutions such as calcium chloride, as they can cause accelerated corrosion that will result in reduced sprinkler system life and potential leakage.

2.4.4 Clearance From Sprinklers to Ceiling

The location of sprinklers relative to the ceiling above has a major impact on the speed of sprinkler operation. The ideal location of the fusible element is between 6 and 10 in. (152 and 254 mm) below the ceiling. If the fusible element is too close to the ceiling, the hot gas flow from a fire can initially flow beneath the sprinkler, delaying operation. If the fusible element is too far below the ceiling, the hot gas will initially flow above the sprinklers, again delaying sprinkler operation at the critical early stage of a fire.

Install suppression mode sprinklers with the center line of the thermal sensing element located a maximum of 13 in. (330 mm) and a minimum of 4 in. (102 mm) below the ceiling. An acceptable alternative is to install the sprinkler so that the deflector is a maximum of 14 in. (356 mm) and a minimum of 5 in. (127 mm) below the ceiling.

Full-scale fire tests showed that the K22.4 (K314) and the K25.2 (K360) pendent suppression mode sprinkler performs satisfactorily when the deflector is located no more than 18 in. (457 mm) below the ceiling.

For corrugated metal deck roofs up to 3 in. (76 mm) deep, measure the distance to the sprinkler from the bottom of the deck. For deeper decks, measure the distance to the highest point of the deck.

For roofs with flexible batting insulation suspended beneath, measure the distance to the sprinkler as the distance from the underside of the roof minus the thickness of insulation. Minimize sag in insulation so that the minimum distance from the fusible element is no less than 4 in. (102 mm) below the insulation at its lowest point.

2.4.5 Obstructions

Effective operation of suppression mode sprinklers requires that water be delivered directly to burning commodities at high volume and high momentum. Obstructions can interfere with the distribution pattern and significantly reduce downward momentum of the water discharge and penetration of the fire plume, resulting in a failure to suppress a fire. In the types of storage protected by suppression mode sprinklers, this will result in an uncontrolled fire.

Testing has clearly shown that even comparatively small obstructions, when they are at critical locations, can result in an uncontrolled fire if the fire starts beneath them.

Obstructions can be located at or near the ceiling, or entirely below sprinklers. These include, but are not limited to: beams, girders, truss and bar joist bottom chords, wind bracing and bridging, ducts, heaters, cable trays, conduit, sprinkler system or other piping, noise abatement curtains, draft curtains, lighting fixtures, etc.

2.4.5.1 Solid Obstructions at Ceiling Level

Obstructions extending from a point at or above the level of a sprinkler to a point below the sprinkler deflector can completely block a significant portion of the sprinkler discharge. Typical examples of this type of obstruction include, but are not limited to: concrete or steel beams, steel girders, joists or trusses whose webs are less than 70% open, draft curtains, etc.

The only way to mitigate this effect is to locate sprinklers in relation to the obstructions such that the “umbrella” of the discharge pattern passes beneath the obstruction.

To accomplish this, locate sprinklers so that the vertical distance from the sprinkler deflector to the bottom of the obstruction and the horizontal distance from the nearest edge of the obstruction are as shown in Figure 2.4.5.1.1.

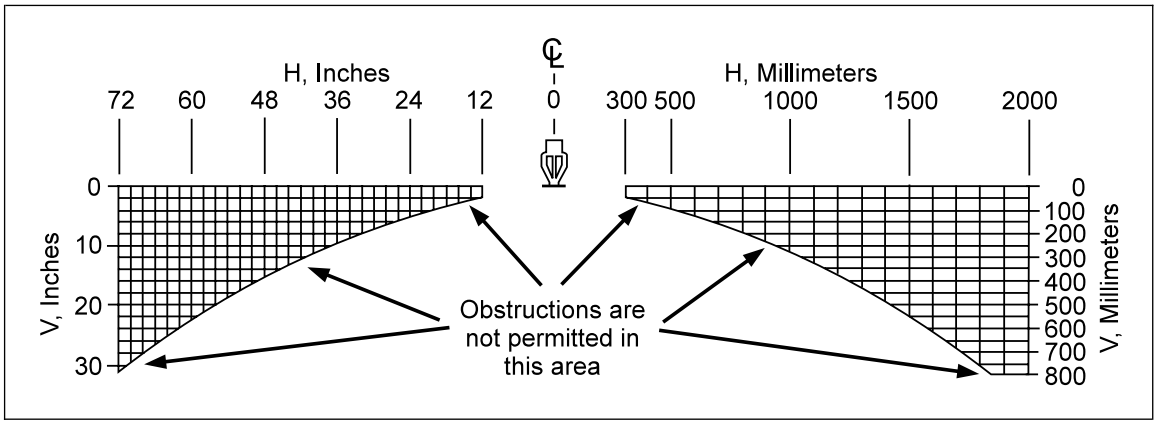

Figure 2.4.5.1.1 Area where obstructions are not permitted.

As an alternative for beams, girders, draft curtains and other obstructions at ceiling level that are no more than 12 in. (305 mm) wide, locate sprinklers on either side of the obstruction no more than 6 ft (1.83 m) from the nearest edge of the obstruction in buildings up to 32 ft (9.75 m) high, and no more than 5 ft (1.52 m) from the nearest edge of the obstruction in buildings up to 45 ft (13.71 m) high. Maintain minimum of 36 in. (914 mm) clearance between the top of storage and the obstruction above it. (see Figure 2.4.5.1.2)

Meeting the requirements of this section will mitigate obstructions created by other objects, although it may not be the most practical solution. Alternate requirements for specific types of obstructions follow.

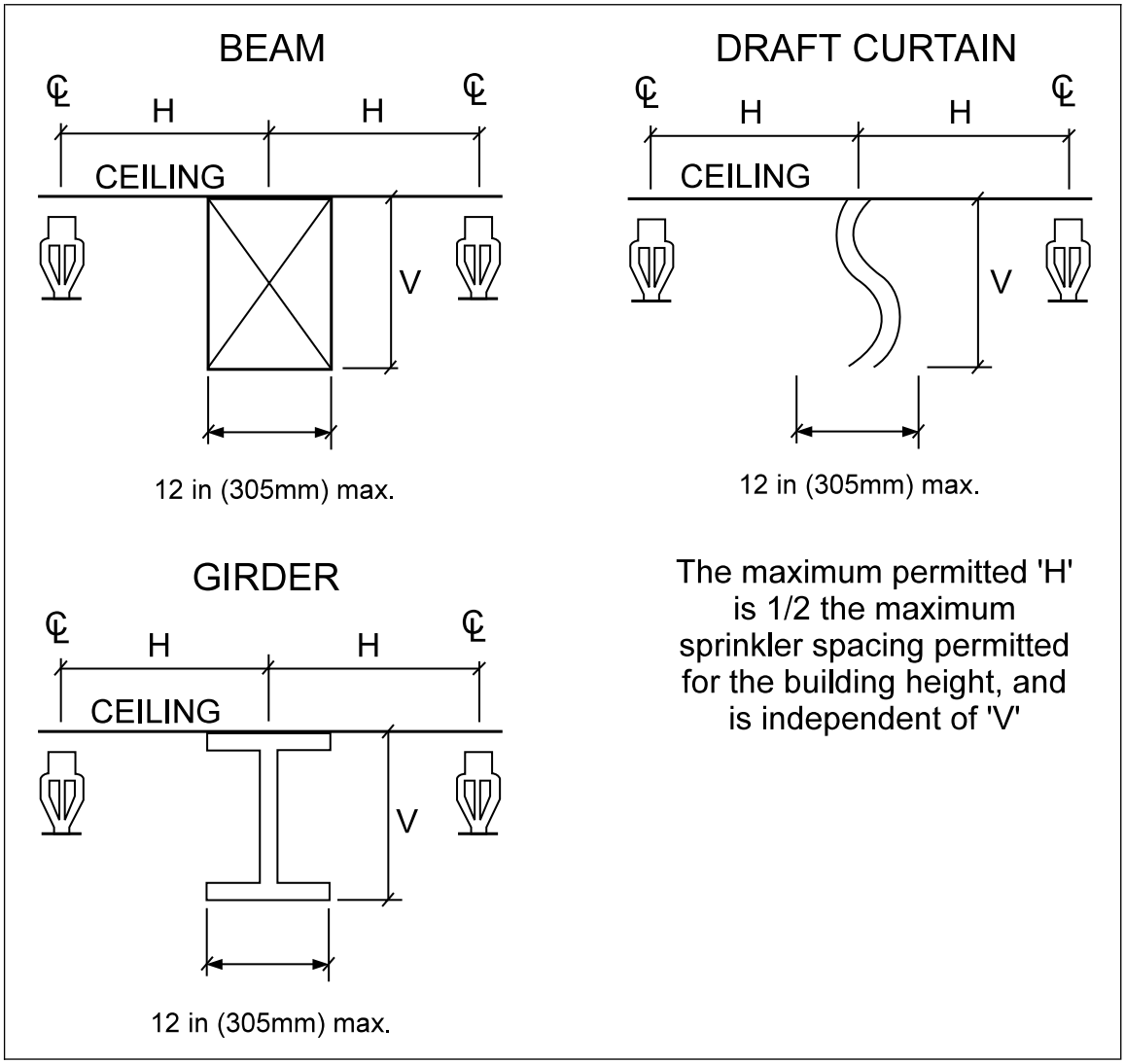

Figure 2.4.5.1.2 Alternative arrangement for obstructions no more than 12 in. (305 mm) wide at ceilings.

2.4.5.2 Open-Web Structural Members at Ceiling Level

While the webs of structural members that are more than 70% open (which can be the case for bar-joists, trusses, etc.) do not obstruct the sprinkler discharge pattern in the way that solid-web members do, the bottom chords of these members can severely obstruct the sprinkler discharge. Bracing and bridging can also severely obstruct the sprinkler discharge.

Locate sprinklers a minimum of 1.0 ft (305 mm) horizontally from the nearest edge of the bottom chord of a bar joist, trusses, or a similar open-web member with a web that is at least 70% open, and from bridging (see Figure 2.4.5.2).

This requirement assumes that there is only one member obstructing sprinkler discharge, and that the nearest obstruction on the other side of the sprinkler is further away from the sprinkler. There are cases (such as roof areas subject to snow drifting) where open-web roof joists or trusses are located close together to support higher loads. Where open-web structural members are located less than 3 ft (914 mm) apart (as measured from the edge of the bottom chords closest to the sprinkler), a solid barrier or suspended ceiling should be installed beneath the members with suppression mode sprinklers located beneath.

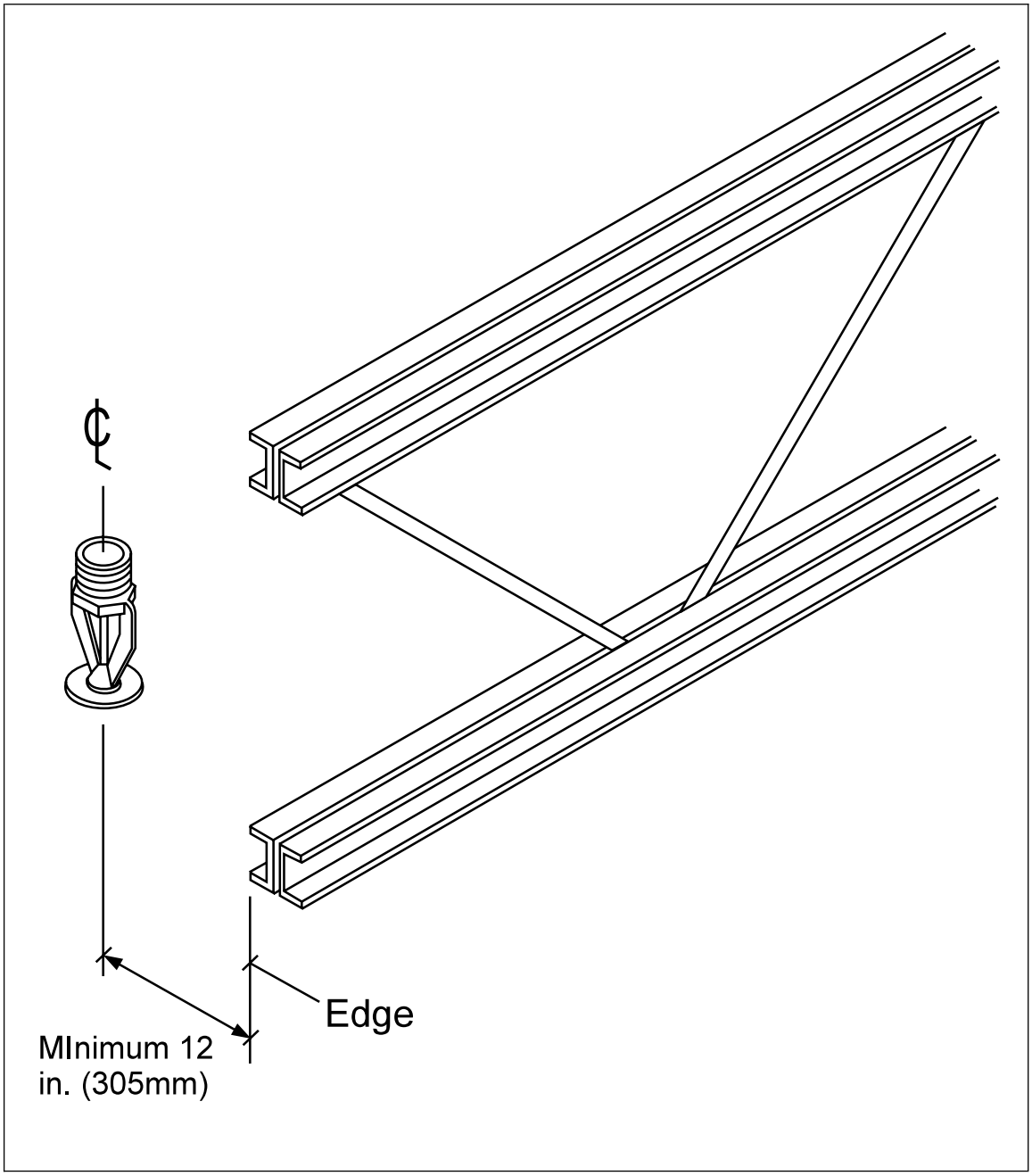

Figure 2.4.5.2 Minimum allowable clearance for bar joists.

2.4.5.3 Obstructions Below Sprinklers

Obstructions located entirely below sprinklers, while they may not create as large an interruption of the distribution pattern of sprinklers, can create "shadows" and reduce the momentum of the sprinkler discharge to the point that a fire will neither be suppressed nor controlled. Testing has shown that a single obstructed sprinkler can result in an uncontrolled fire if it is in a critical location and a fire starts beneath it.

Individual obstruction (see Appendix A for definition) is ¾ in. (19 mm) wide or less and at least 4 in. (100 mm) below the sprinkler deflector may be ignored.

Obstructions located more than 36 in. (914 mm) below suppression mode sprinklers will not disrupt the discharge pattern, but cannot be ignored because they can obstruct water penetration into flues in storage. Obstructions that are located directly over flues must be at least 36 in. (914 mm) above the flue.

2.4.5.3.1 Upright Suppression Mode Sprinklers

Full-scale fire testing done in conjunction with the Approval of the K14.0 (K200) upright suppression mode sprinkler showed small obstructions located directly below the sprinklers have less impact on the performance of the tested sprinkler than on pendent suppression mode sprinklers. Therefore, the obstruction requirements of this standard can be relaxed as follows:

When FM Approved upright suppression mode sprinklers are used obstructions below sprinklers can be ignored if:

- They are open-web bar joists or trusses having chords no more than 4 in. (102 mm) wide, or
- They are bridging or wind bracing no more than 4 in. (102 mm) wide, or
- They are individual (see glossary for definition)pipes and conduit 4 in. (102 mm) in diameter or less, or individual groups of smaller pipe or conduit having a total width of 4 in. (102 mm) or less.

2.4.5.3.2 All Other Suppression Mode Sprinklers

Obstructions below sprinklers that meet the requirements of Figure 2.4.5.1.1 are acceptable. Otherwise, the following requirements must be met:

1. Obstructions Below Sprinklers wider than ¾ in. (19 mm) and no wider than 2 in. (51 mm):

   Locate the sprinkler deflector at least 12 in. (305 mm) horizontally from the nearest edge of the obstruction or locate the obstruction at least 24 in. (610 mm) below the deflector (see Figure 2.4.5.3.1)

2. Continuous Obstructions Below Sprinklers wider than 2 in. (51 mm) and no wider than 12 in. (305 mm):

   Locate the sprinkler deflector at least 12 in. (305 mm) horizontally from the nearest edge of the obstruction (see Figure 2.4.5.3.2).

3. Continuous Obstructions Below Sprinklers wider than 12.0 in. (305 mm) and no wider than 24.0 in. (610 mm):

   Locate the sprinkler deflector at least 24.0 in. (610 mm) horizontally from the nearest edge of the obstruction (see Figure 2.4.5.3.3).

4. Obstructions Below Sprinklers wider than 24.0 in. (610 mm):

   Satisfy the requirements in Figure 2.4.5.1.1 or:

   - If the obstruction is continuous, flat, horizontal and solid, install a line of sprinklers with the thermal sensing elements located a maximum of 13.0 in. (330 mm) below the obstruction. Use the same type sprinkler used at the ceiling, and space them a maximum of 8.0 ft (2.43 m) apart. Maintain at least 36 in. (914 mm) between the sprinkler deflector and the top of the storage (see Figure 2.4.5.3.4).
   - If the obstruction is continuous and not flat (as in the case of a circular duct) or is not solid (as in the case of grouped conduit), install a flat barrier under the obstruction at least as wide as the obstruction. Install a line of sprinklers below the barrier as described in the previous paragraph (see Figure 2.4.5.3.5).
   - If the Obstructions Below Sprinklers is not continuous circular or rectangular (such as a light) with a maximum dimension of 24.0 in. (610 mm), locate the sprinkler deflector at least 12 in. (305 mm) horizontally from the nearest edge of the obstruction (see Figure 2.4.5.3.6).

2.4.6 Water Demand and Duration

Design sprinkler systems and hose demands to meet the requirements of the appropriate occupancy standard.

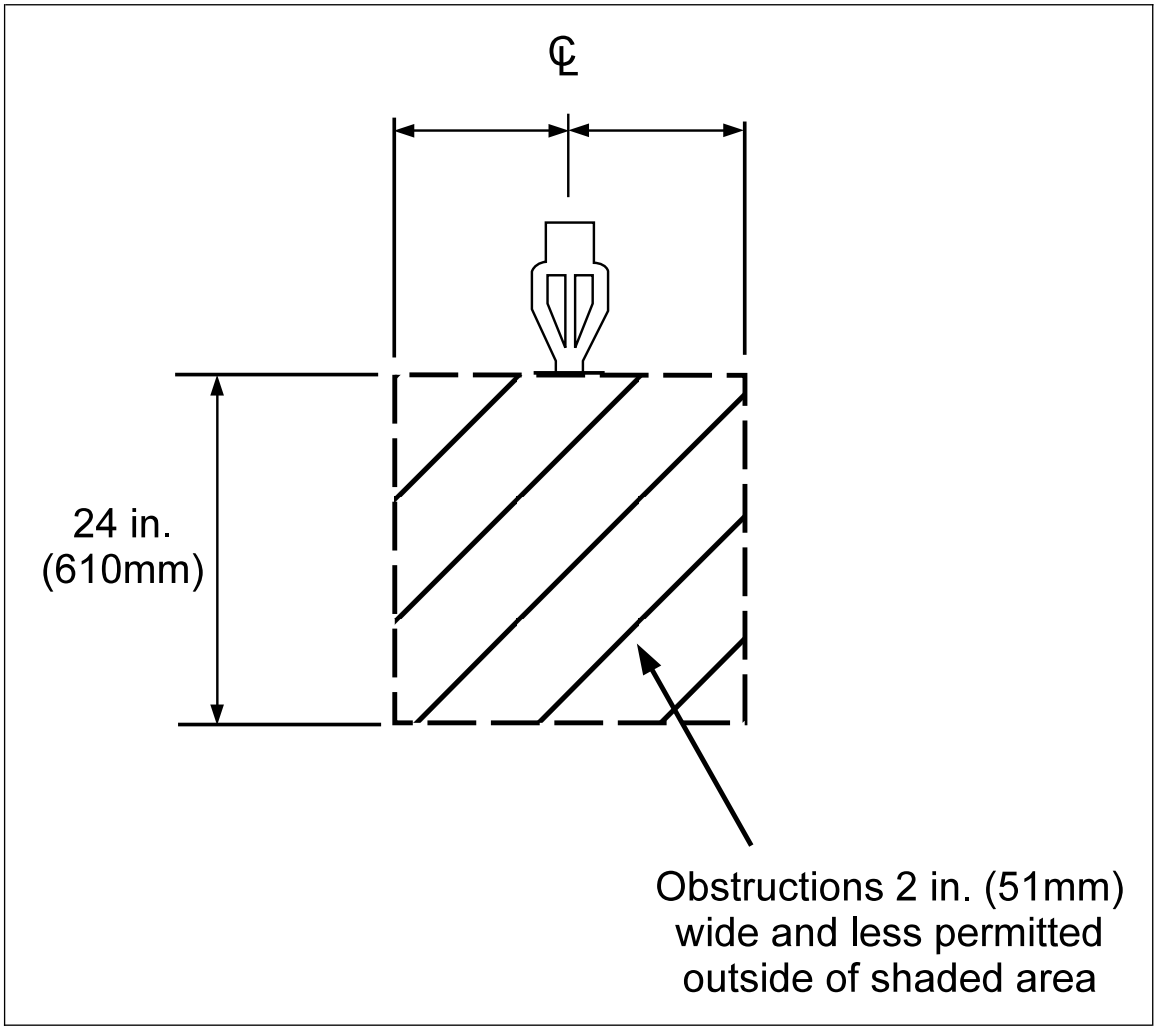

Figure 2.4.5.3.1 Obstructions below sprinklers no wider than 2.0 in. (51 mm).

2.4.7 Sprinkler Spacing

Space suppression mode sprinklers horizontally no less than 8 ft (2.4 m) apart. Space them no more than 12.0 ft (3.66 m) apart in buildings up to 30 ft (9.14 m) high, and no more than 10.0 ft (3.05 m) apart in higher buildings. Limit the area of coverage to a minimum of 64 ft^2 (6 m^2) and a maximum of 100 ft^2 (9.3 m^2).

Elimination of obstructions is critical to the success of suppression mode sprinklers. There can be cases where a slight extension in sprinkler spacing and coverage in isolated areas can eliminate obstructions. If increasing spacing between two adjacent heads on branch lines or between two adjacent branch lines can eliminate obstructions, then the following extensions are allowable:

- In buildings up to 30 ft (9.14 m) high, the maximum spacing of 12.0 ft (3.66 m) and area of coverage may be increased to 110 ft^2 (10.7 m^2) for those sprinklers that need to be moved in order to be at least 12.0 in. (305 mm) from joists.
- In buildings over 30 ft and up to 40 ft (9.14 m up to 12.19 m) high, the maximum spacing of 10.0 ft (3.05 m) may be increased to 11.0 ft (3.35 m), with a maximum area of coverage of 110 ft^2 (10.2 m^2), for those sprinklers that need to be moved in order to be at least 12.0 in (305 mm) from bar joists.

NOTE: These extensions apply only to a maximum of two adjacent sprinklers on branch lines or two adjacent branch lines. See Figure 2.4.7.1.

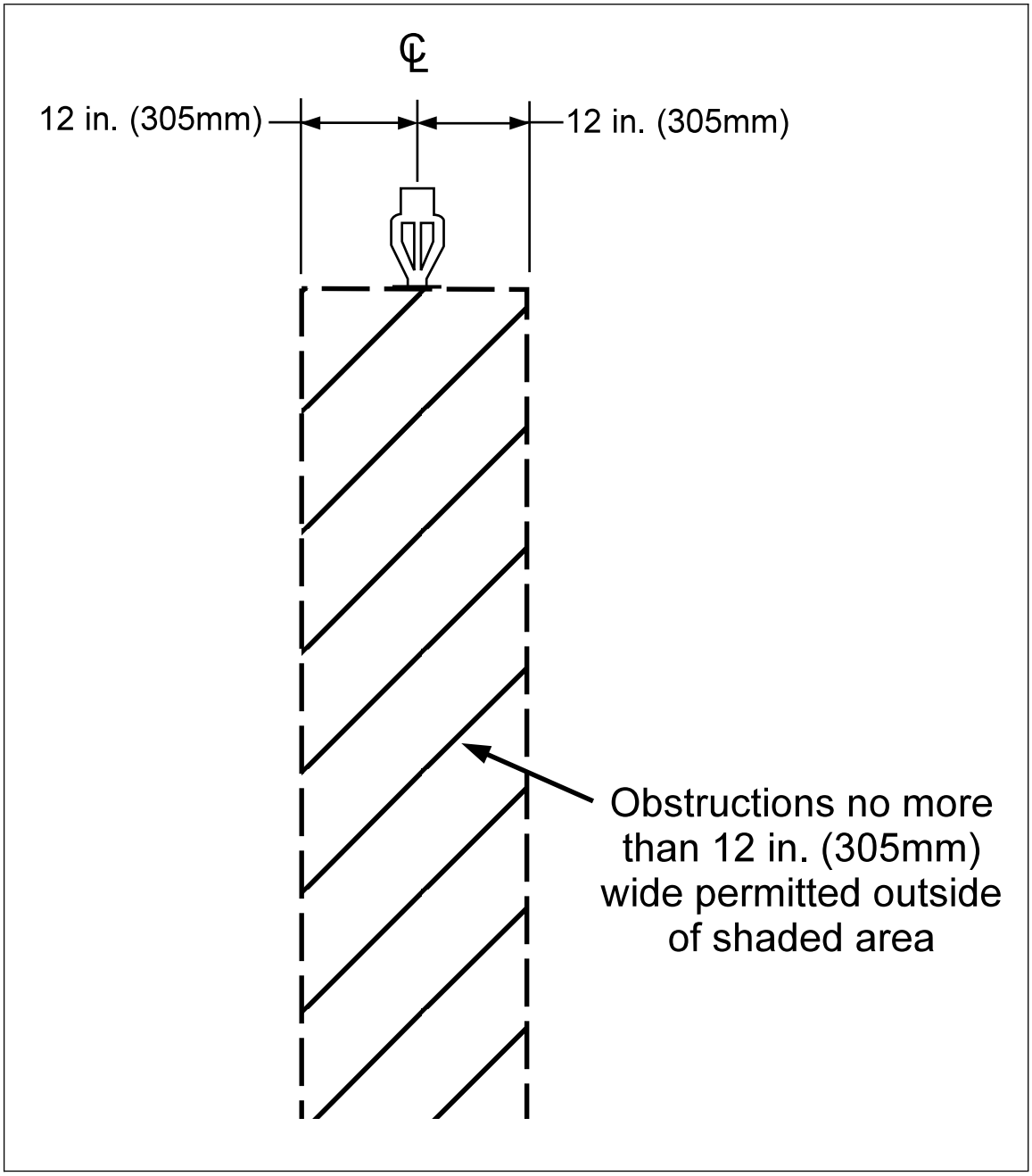

Figure 2.4.5.3.2 Obstructions below sprinklers no wider than 1 ft (305 mm).

2.4.8 System Hydraulic Design

Design the system to meet or exceed the minimum pressure specified for the type of sprinkler, storage height, and building height in the appropriate occupancy standard. Use the nominal K-factor specified in FM Approval listing for the sprinkler.

Where a 12-sprinkler design area is specified in the occupancy standard, base the design on the most hydraulically remote twelve sprinklers, flowing four sprinklers on three branch lines. When branch lines contain fewer than four sprinklers, flow whole branch lines and any needed additional sprinklers on an adjacent branch line to achieve a 12-sprinkler total.

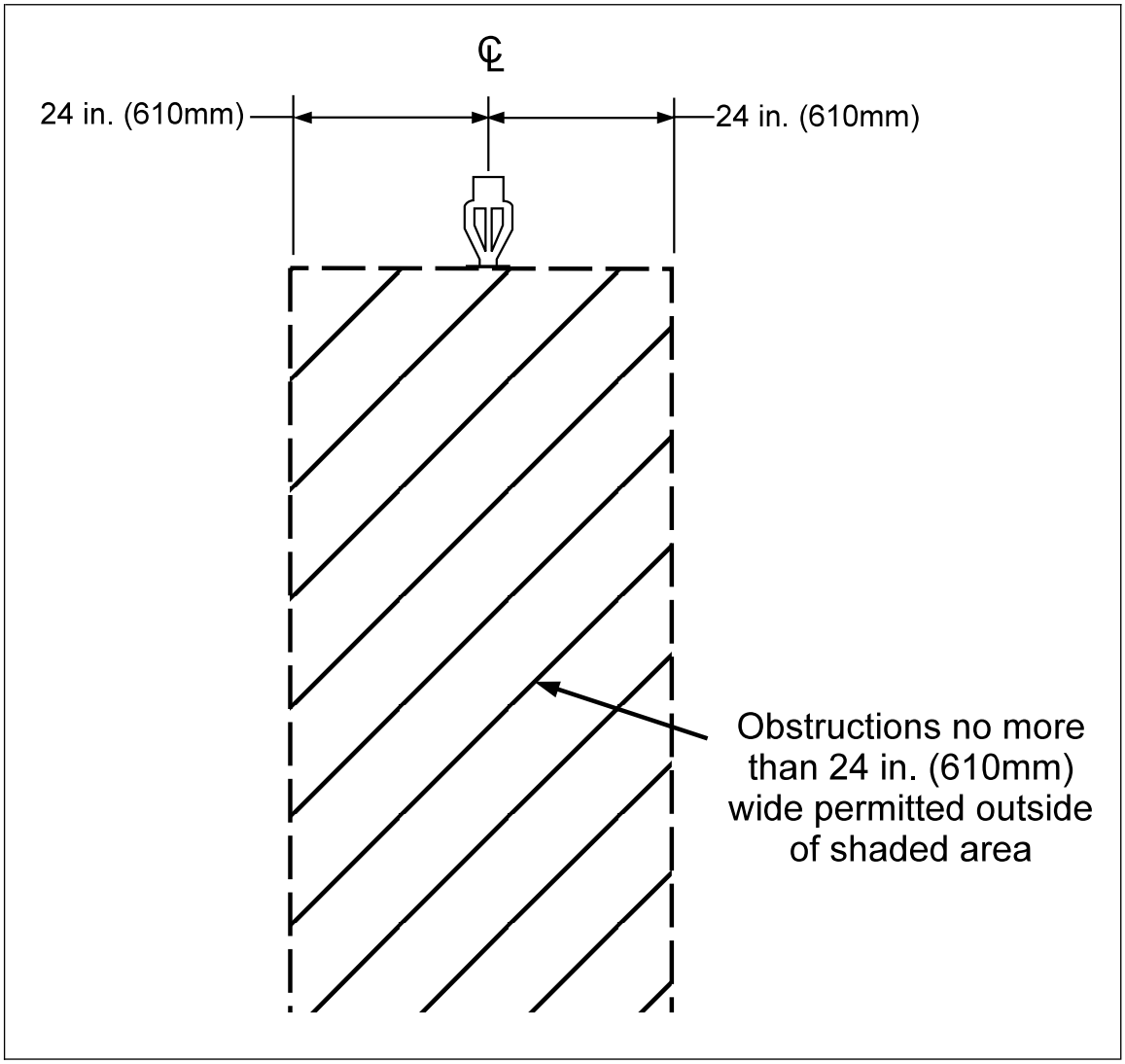

Figure 2.4.5.3.3 Obstructions below sprinklers wider than 1 ft (305 mm) and no wider than 2 ft (610 mm).

Where a larger number of sprinklers is specified, select the hydraulically most remote area containing the required number of sprinklers, using a 1.4 shape factor in accordance with Data Sheet 2-8N.

When additional sprinklers are installed under obstructions, conveyors, or walkways, include the required sprinklers in the design, balanced with the ceiling sprinkler system. The design area is the most demanding combination of ceiling sprinklers and additional sprinklers below them.

2.4.9 Hose Connections

Provide fixed small hose stations supplied with no more than 100 ft (30 m) lengths of 1-½ in. (40 mm) hose, located so that all storage areas can be reached. Experience has proven small hose to be far more effective than portable fire extinguishers in extinguishing fires at the incipient stage.

Supply small hose in one of the following ways:

- From a separate metallic piping system for small hose stations
- From hose connections at sprinkler risers upstream of sprinkler system control valves
- From adjacent sprinkler systems

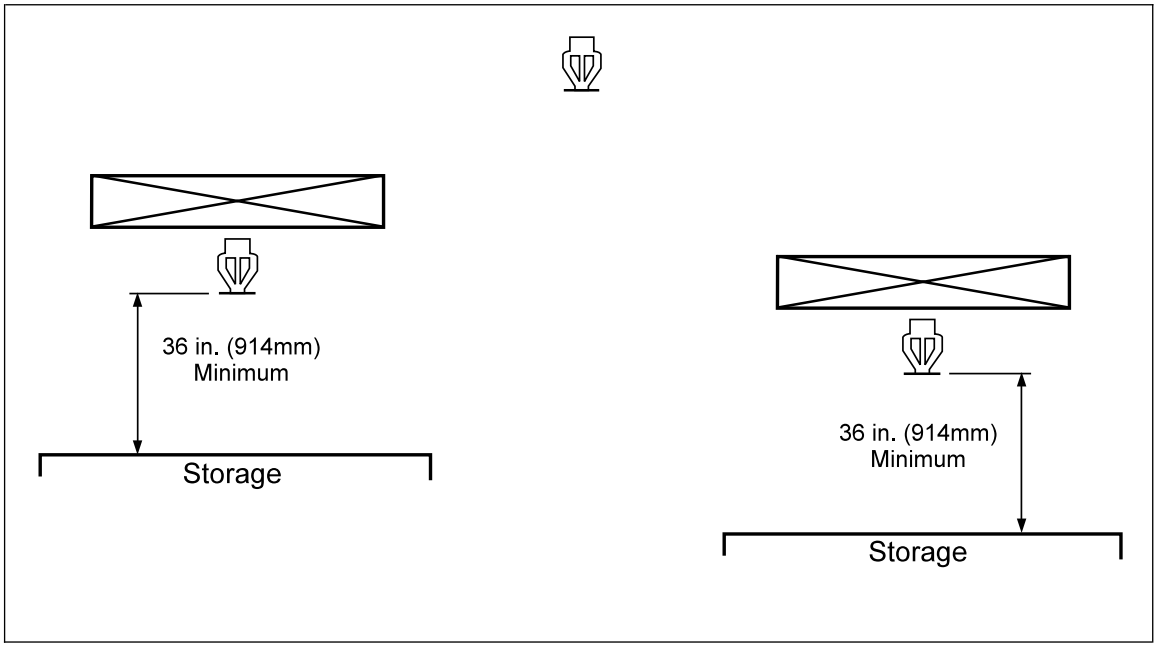

Figure 2.4.5.3.4 Flat, horizontal solid obstructions below sprinklers wider than 2 ft (610 mm).

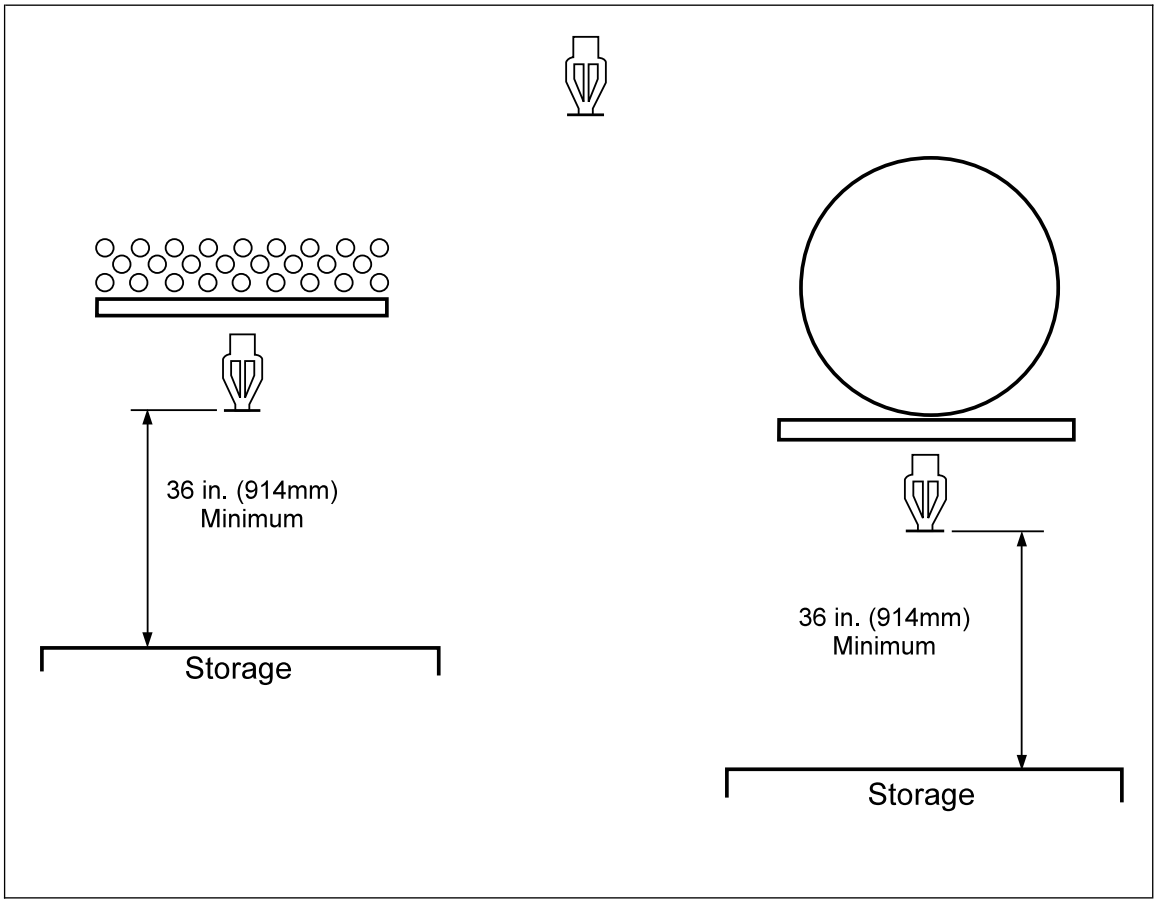

Figure 2.4.5.3.5 Obstructions below sprinklers wider than 2 ft (610 mm) not flat or not solid.

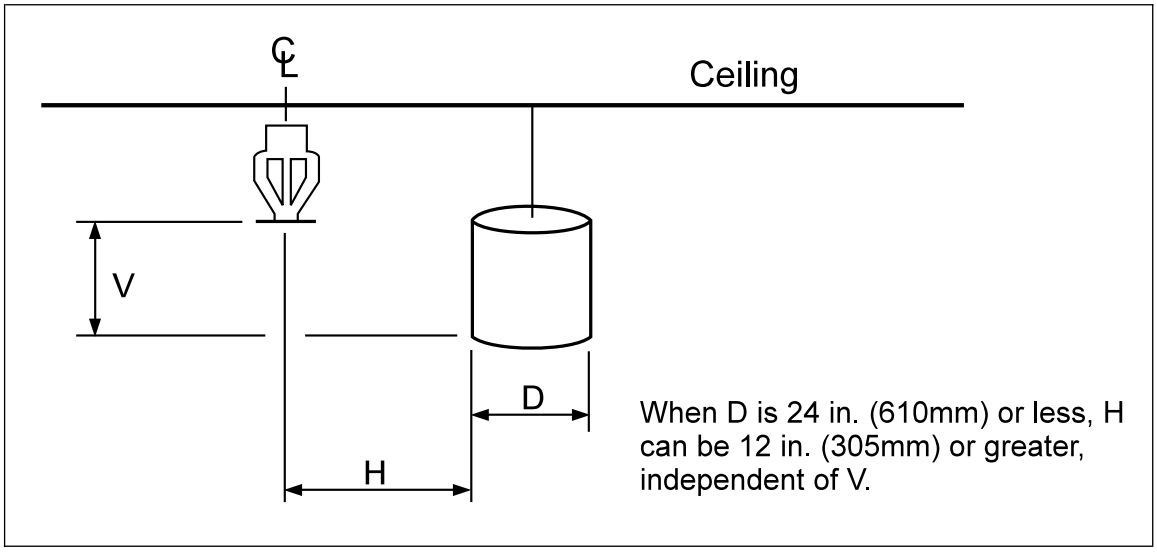

Figure 2.4.5.3.6 Round or rectangular obstructions below sprinklers < 24.0 in. (305 mm) wide.

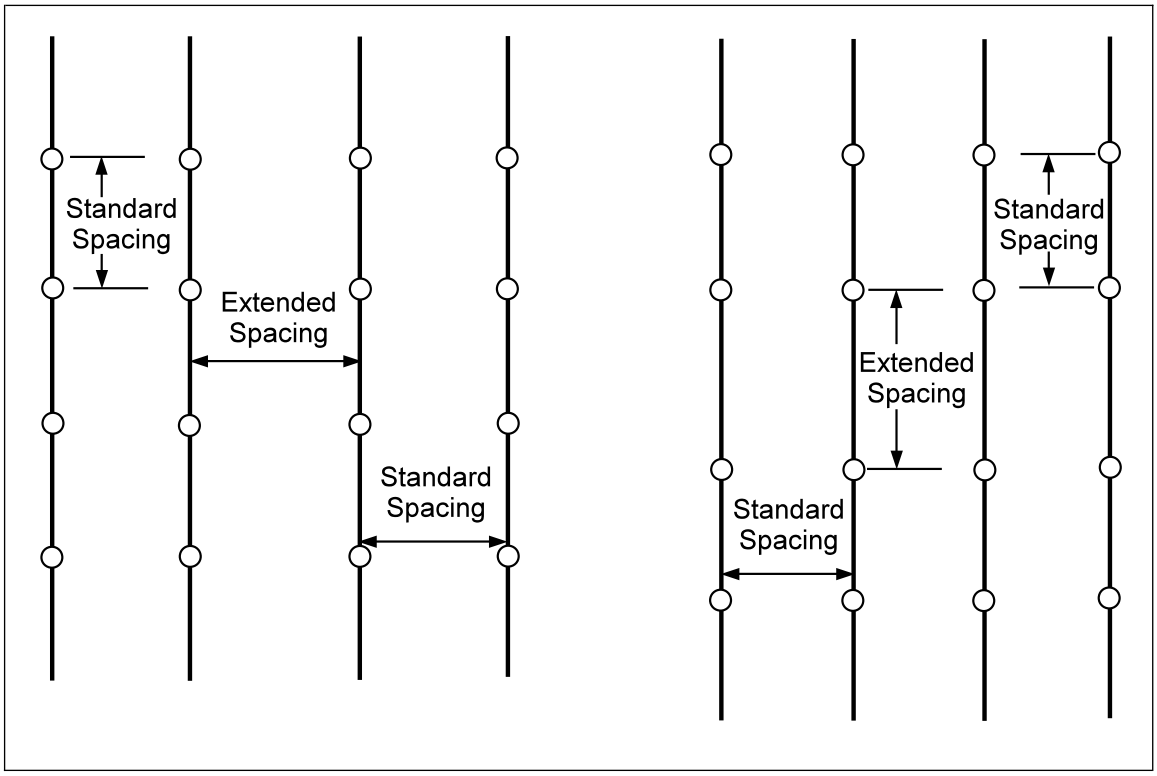

Figure 2.4.7.1 Permissible sprinkler spacing extension.

3.0 SUPPORT FOR RECOMMENDATIONS

The data supporting the need to address obstructions originates from two primary sources:

- The results of tests in the full-scale fire test program, which were designed to simulate one sprinkler being plugged.
- Actual delivered density (ADD) and full-scale testing to evaluate the effect of bar joists on suppression mode sprinkler performance.

In the full-scale fire test program, tests were run to simulate a plugged sprinkler. Two similar tests were run, one for 30 ft (9.14 m) high buildings and one for 40 ft (12.19 m) high buildings. In both tests, the ignition point was centered between two sprinkler outlets, one of which had an suppression mode sprinkler installed and one that had a plug installed. In the test for 30 ft (9.14 m) high buildings, eleven sprinklers opened and the test was considered successful, because more than twelve sprinklers did not operate, and fire spread was acceptable. However, a similar test for 40 ft (12.19 m) buildings opened twenty sprinklers and fire control was not achieved. This showed a need for tighter control of obstructions in buildings higher than 30 ft (9.14 m).

In the ADD testing, obstructions ranging from ¾ in. (19 mm) to 4 in. (102 mm) were used to simulate the effect of bridging, wind bracing, bar-joist chords, and similar small obstructions. ADD measurements were made for a variety of combinations of horizontal and vertical distances between sprinklers and obstructions. The results indicated that, if a fire starts under one sprinkler obstructed by such objects, a failure to suppress or control the fire could result.

In the first full-scale test, a typical bar-joist condition was simulated. A K14.0 (K200) suppression mode sprinkler was installed in the web of a 22.0 in. (559 mm) deep bar joist, 8.0 in. (203 mm) above the bottom chord, which was 4.0 in. (102 mm) wide. The bar joist was installed in a 40 ft (12.19 m) test site at the FM Global Test Center, and the test array was 30 ft (9.14 m) high rack storage of the standard FM Global cartoned unexpanded plastic commodity. The fire was ignited in the intersection of the longitudinal and transverse flue of the rack, which was directly underneath the obstructed sprinkler. The fire was not suppressed, and rapidly grew out of control.

In the second test, which was identical to the first except that the sprinkler was moved out of the web of the joist, the fire was suppressed, showing that locating sprinklers 12 in. (305 mm) from bar joists will minimize the effect of obstructions.

In the final test, conditions were identical to the first test, except that a steel angle 1.5 in.(38 mm) wide was used as the obstruction. As in the first test, the fire was not suppressed, and rapidly grew out of control.

3.1 Loss History

There are a total of six known fires involving suppression mode sprinkler protection. In all of these incidents, suppression mode protection was successful and no more than four sprinklers operated.

In the two incidents for which detailed information was available, the sprinklers involved were not obstructed.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-12, *Ceilings*.
Data Sheet 2-8N, *Installation of Sprinkler Systems*.

APPENDIX A GLOSSARY OF TERMS

Approved: references to ‘‘Approved’’ in this data sheet means the product and services have satisfied the criteria for FM Approval. Refer to the *Approval Guide* for a complete listing of products and services that are FM Approved.

Individual: objects and obstructions are considered ‘‘individual’’ only if they are separated from the nearest adjacent object or obstruction by a distance of at least 6 times their least dimension. For example, a group of six 1 in. (25 mm) diameter conduit spaced 1 in. (25 mm) apart would be treated as a group and would create an obstruction 11 in. (280 mm) wide. If the same group of conduit were spaced 6 in. apart, it would be treated as six 1-inch wide objects.

K (K Factor): the K-factor of a sprinkler is a function of its orifice size and allows the calculation of discharge from the sprinkler using the formula:

$$Q = K(P^{½})$$

Where Q is in GPM (l/min) and P is in PSI (BAR). The K-factor and sprinkler orientation are to identify the various types of suppression mode sprinklers.

APPENDIX B DOCUMENT REVISION HISTORY

January 2001. Engineering Bulletin 14-0 that provides guidelines for the use of the newly approved Viking Model VK520 K14 upright suppression mode sprinkler was added.

May 1995. First publication.