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Fire Protection of Windows Using Sprinklers

by A.K. Kim and G.D. Lougheed

Building owners and designers have been limited in the extent to which they can use glazing in fire-rated separations. This Update presents the results of IRC research on the use of dedicated sprinkler systems to protect glazing in fires and provides guidelines that will ensure effective protection in different situations.

There is an increasing demand for the use of glazing assemblies in fire separations and in the building envelope for aesthetic, security and economic reasons. Ordinary glass cannot be used because thermal stresses will cause it to shatter after only a few minutes of exposure to fire. Therefore, for fire-rated assemblies, North American model building codes limit vertical glazing to wired glass in steel frames with a maximum glazing dimension of 1400 mm. This represents a severe restriction for designers.

To overcome these limitations without compromising fire safety, fire researchers at NRC's Institute for Research in Construction (IRC) developed a protection method involving the use of a dedicated automatic sprinkler system that applies a film of water to the glazing assembly.[1] The IRC investigations demonstrated that tempered or heat-strengthened glass (which, by itself, provides only minimal passive fire protection), protected by such a sprinkler system, will remain intact for more than 1 hour. Based on these studies, the sprinkler-protection system has been accepted by some code authorities for use in fire separations in buildings for specific applications.

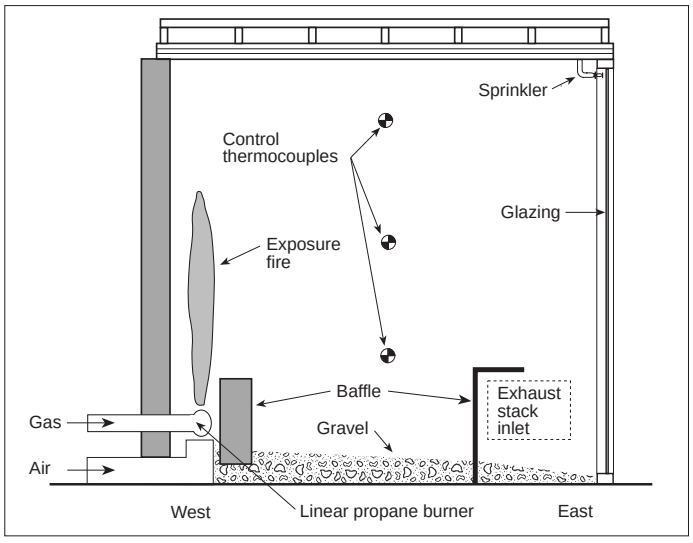

Figure 1. Section through test room

Thermal Shock

Tests with a small-scale radiant panel demonstrated that cold water applied to hot glazing can cause premature failure of the glass.[2] Without water protection, tempered and heat-strengthened glazing can sustain a glazing temperature on the exposed side of more than 350°C. However, when water was sprayed onto the hot glazing, the glazing failed at much lower temperatures. The critical temperatures established for heat-strengthened and tempered glazing are 150–165°C and 200°C, respectively.[2] The critical temperature for plain glass (80–90°C) is too low to allow for effective protection using a sprinkler system. These investigations established that in order for a sprinkler to provide effective protection, it must be activated before the glazing temperature exceeds its critical level.

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NRC Test Facility

The full-scale fire tests on sprinkler-protected window assemblies were conducted in a room with a floor area of 3600 mm by 3300 mm and a ceiling height of 3300 mm.[2] A sketch of the test facility is shown in Figure 1.

Fire exposure was provided by a linear propane burner installed near the floor adjacent to the west wall of the test room. Combustion air was supplied through a perforated steel duct located beneath the burner. Combustion products and steam were withdrawn from the room using natural ventilation through two exhaust stacks with a 600-mm by 450-mm cross-section.

Fire Exposure

The fire exposure was established by conducting a preliminary test without sprinkler operation to determine the propane flow rate required to maintain the average temperature in the enclosed compartment as close as possible to the standard time-temperature curve, used for determining the fire resistance of building assemblies.[3]

The propane flow rate determined in the calibration test was then used for the tests with sprinkler protection. The only sprinklers operating during the tests were those used to protect the window assembly. Although such a system would, in most cases, be used in a building with overall sprinkler protection, it is assumed that the window-protection system would be a dedicated one, separate from the main sprinkler system.

Design Considerations

Specific design considerations for a dedicated sprinkler-protection system for a full-height (floor to ceiling) window assembly are addressed below. These include:

- window width,
- mullion depth, and
- multi-sprinkler systems.

For all tests, a fast-response sprinkler was used.[1,2,4] In the tests, a sprinkler was installed in a horizontal orientation and positioned at the top centre of a window assembly. The centreline of the sprinkler's deflector was located 50 mm below the top window frame, and the deflector positioned 13 mm from the glass (see Figure 2). The sprinkler was activated by the fire, and the water pressure at the sprinkler was maintained at 145 kPa.

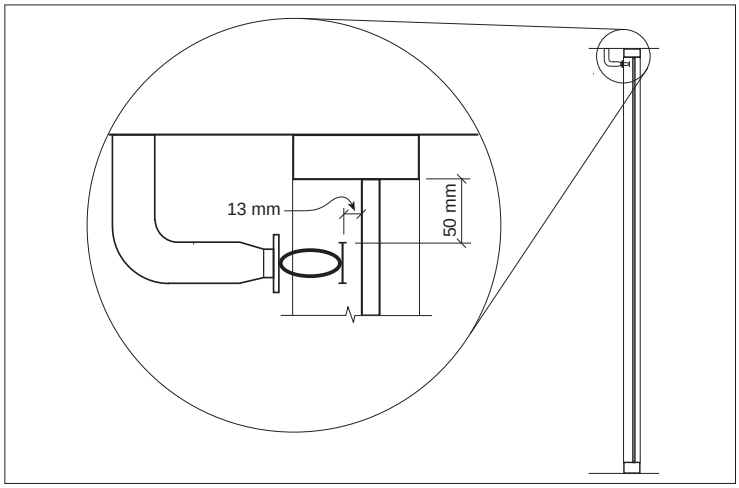

Figure 2. Sprinkler location relative to full-height window assembly (section)

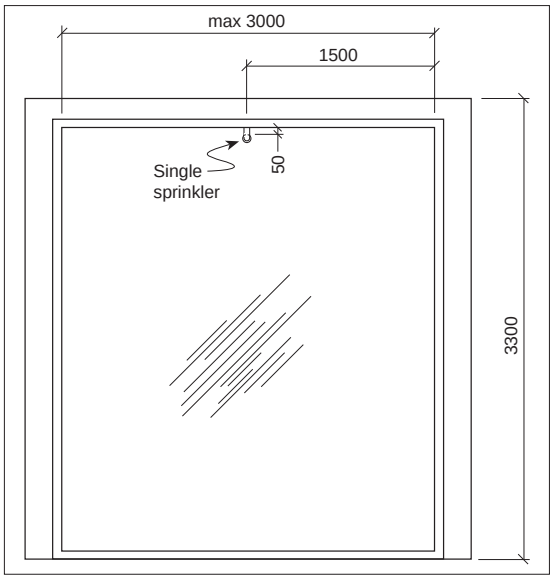

Figure 3. Location of single sprinkler for protection for full-height window assembly (elevation)

To provide adequate protection, the fast-response sprinkler must have a temperature rating of 74°C and a Response Time Index (RTI) of 22.7 $m^{1/2}s^{1/2}$ or lower.

Window Width

Tests were conducted to determine the maximum width of glazing that can be protected using a single sprinkler. For glazing 3000 mm wide, with no separating mullion, the water spray from a single sprinkler provided good coverage for all surfaces of the window and frame, with adequate water film flow on the glazing surface (see Figure 3). Glazing temperatures reached steady conditions in less than 10 minutes and the window system maintained its integrity for the 2-hour test duration.

Mullion Depth

Tests were conducted with 10-mm and 25-mm deep mullions. The results indicated that mullions with depths of 25 mm or more interfered with the water spray to the glazing on both sides of the mullion. The conclusion is that a single sprinkler will not provide adequate protection for such a glazing assembly. For windows with mullions more than 25 mm deep, therefore, multi-sprinkler protection systems should be considered.[4]

Multi-Sprinkler Systems

When a multi-sprinkler system is used to protect a wide window or a window with a deep mullion, the water spray from the first

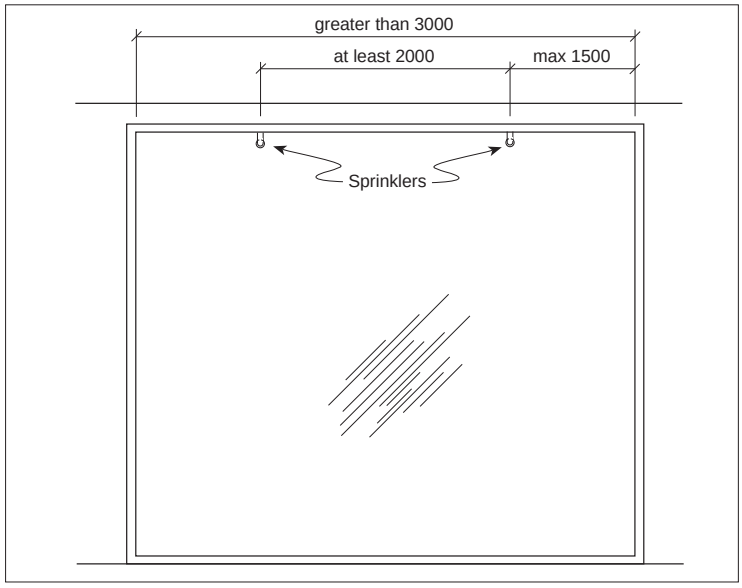

Figure 4. Location of sprinklers in multi-sprinkler system for protection of wide windows (elevation)

sprinkler activated could delay the activation of an adjacent sprinkler. Tests were conducted to study the problem.

For very wide windows without a mullion, the activation times of sprinklers, located 2000 mm from a sprinkler operating at a pressure of 145 kPa, were in the range of 5 to 7 minutes. However, the critical temperature for the glazing was not reached until 10 to 11 minutes. As such, the second sprinkler would activate before critical conditions are reached. Therefore, a wide window or a window without mullions can be protected by a multi-sprinkler system, without the concern of delayed sprinkler activation, when sprinklers are located at least 2000 mm apart (see Figure 4).[4]

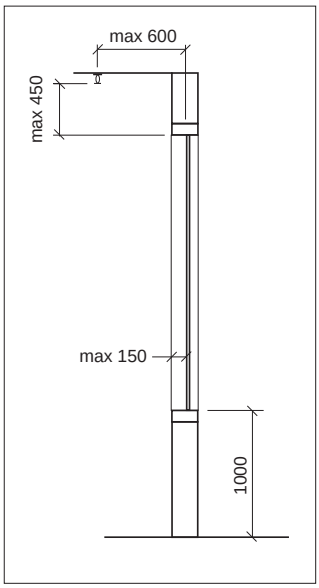

Figure 5. Limiting distances for ceiling-mounted pendent sprinklers (section)

When there is a centre mullion (of at least 50-mm depth) between the sprinklers, the influence of water spray from the adjacent sprinkler is not significant; in this case, the second sprinkler activated in less than 40 seconds.[2]

The activation time of the second sprinkler is dependent on sprinkler orientation and location. If the geometry is changed, the overall protection system should be evaluated to determine the effectiveness of the dedicated sprinkler system.

Ceiling-Mounted Sprinklers

The use of ceiling-mounted pendent sprinklers to protect glazing assemblies is of particular interest to building designers for aesthetic reasons. A study to determine the effectiveness of such a system revealed two concerns: sprinkler activation time and water spray pattern onto the glazing surface.

Sprinkler activation time. Ceiling-mounted sprinklers, both standard and fast-response, did not activate in time to protect full-height tempered glazing from a small fire located on the floor adjacent to the glass.[4] This limits the use of ceiling-mounted sprinklers in protecting glazing assemblies. They can, however, be used in those cases where the base of the glazing is at least 1000 mm above the floor. In such instances, the chances of having a localized fire impinging directly on the glazing are small and, thus, the system would not likely be faced with this challenge.

Spray pattern. A series of spray-pattern tests indicated that the probability of glass breakage from fire exposure increases generally with an increase in sill depth, an increase in sprinkler height above the top of the glazing and an increase in sprinkler distance from the window.[2] This is based on the size of the dry area on the glazing observed for each configuration. As the dry area increases, there is an increased probability of glass breakage from thermal stress. Based on these studies, maximums for each parameter were established as follows (see Figure 5):

- a sill depth of 150 mm,
- a sprinkler height above the window of 450 mm, and
- a sprinkler distance of 600 mm from the window.[4]

For design purposes, the three parameters are interrelated. The designer should select distances that will maximize water spray to all areas of the glazing.

Fire tests using a ceiling-mounted sprinkler with a 1800-mm-wide tempered glazing system at these maximum distances showed that the water spray was sufficient to provide 1-hour fire protection.

If a ceiling-mounted fast-response sprinkler is located at an ideal position — 300 mm away from the glazing surface, and 300 mm above the top of a window with a window-sill depth of 50 mm or less — the water spray provides sufficient protection for a window assembly with tempered glazing and a maximum width of 2600 mm (see Figure 6) for at least one hour.[2] For a wider window, a multi-sprinkler system should be used. The delay in sprinkler

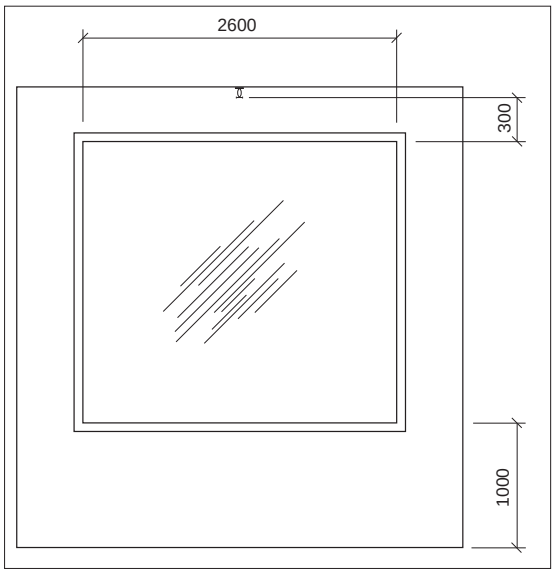

Figure 6. Location (ideal) of ceiling-mounted pendent sprinkler relative to window assembly (elevation)

activation due to adjacent sprinkler operation is not a problem if the sprinklers are spaced at least 1800 mm apart.

Summary

The IRC studies indicated that tempered or heat-strengthened glazing could be protected for more than one hour using a dedicated sprinkler system. However, there are certain limitations on glazing width, mullion depth, the use of single vs. multi-sprinklers, and the use of ceiling sprinklers. For the sprinkler system to perform effectively in protecting window assemblies, these limitations must be taken into account. They are summarized as follows:

- A dedicated fast-response sprinkler can be used to protect a full-height window assembly from both a large compartment fire and a small fire located on the floor immediately adjacent to the glazing. The sprinkler should be mounted adjacent to the glazing at the top centre of the window assembly.
- A single sprinkler should not be used to protect glazing wider than 3000 mm.
- A single sprinkler should not be used to protect a window assembly with a mullion having a depth of 25 mm or more.
- A multi-sprinkler system can be used to protect glazing wider than 3000 mm if the sprinklers are spaced at least 2000 mm apart.
- If there is a centre mullion with a depth of at least 50 mm located between the sprinklers, the spacing between the sprinklers need not be limited.
- A ceiling-mounted pendent sprinkler can be used to protect a window assembly whose base is at least 1000 mm above the floor.
- For a ceiling-mounted pendent sprinkler, the maximums for certain parameters were established as follows: a sill depth of 150 mm, a sprinkler height above the window of 450 mm, and a sprinkler distance from the window assembly of 600 mm. Because these three parameters are interrelated, the designer should select distances that maximize water spray to all areas of the glazing.
- For a ceiling-mounted fast-response sprinkler at the ideal location (300 mm above the window and 300 mm from a window with a sill depth of 50 mm or less), glazing with a maximum width of 2600 mm can be protected for up to 1 hour.
- For multi-sprinkler arrangements mounted on the ceiling, the sprinklers should be spaced at least 1800 mm apart.

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