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Sprinkler-Vent and Spray Nozzle Systems for Fire Protection of Openings in Fire Resistive Walls and Ceilings - The State-of-the-Art and a Plan for Future Research Work

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Center for Fire Research
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

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Final Report
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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*
Jordan J. Baruch, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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SI CONVERSION UNITS

In view of the present accepted practice in this country for building technology, common U.S. units of measurement have been used throughout this document. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measures, which gave official status to the metric SI system of units in 1960, assistance is given to the reader interested in making use of the coherent system of SI units by giving conversion factors applicable to U.S. units in this document.

Length

1 in = 0.0254* meter (m)

Temperature

$t_{°C} = 5/9\ (t_{°F} - 32)$*

Torque

1 in-lb = 0.113 meter-newtons

*Exactly

SPRINKLER-VENT AND SPRAY NOZZLE SYSTEMS FOR FIRE PROTECTION OF OPENINGS IN FIRE RESISTIVE WALLS AND CEILINGS - THE STATE-OF-THE-ART AND A PLAN FOR FUTURE RESEARCH WORK

John G. O'Neill

Abstract

A review of literature was conducted to determine the state-of-the-art of automatic sprinkler, sprinkler-vent and spray nozzle methods of protecting openings in fire resistive assemblies. A review of nationally used model building codes and standards indicated that they have varying provisions for these types of systems. Generally, the use of these systems is only applied to escalator openings in fully sprinklered buildings. Previous experimental work, however, demonstrated that these systems can also be effective in preventing passage of heat and smoke through other types of openings in structural assemblies.

An outline of a planned research project and a description of the test facility are given. The project will develop design parameters for sprinkler-vent and spray nozzle methods for protecting stairways and other openings through floor ceiling assemblies. Results from this project may suggest improvements to current codes and standards involving these systems and possibly permit their wider use in unsprinklered buildings.

Key Words: Automatic sprinkler; building code; smoke movement; spray nozzle; stairway protection; ventilated stair.

1. INTRODUCTION

Protection of openings in buildings against passage of heated gases and smoke has been a primary feature in design of buildings to make them fire safe. Building codes establish fire resistance requirements for structural building elements to prevent structural collapse and to contain fires for a prescribed time period to permit automatic or manual extinguishment. Partitions and ceilings which enclose exit ways are required by codes to be rated in order to prevent passage of heat, flames, and smoke within a given time to allow safe evacuation of the building occupants.

Openings through key barriers should be minimized; however, they are obviously necessary for passage of personnel, commodities, and utility services. Adequate protection of openings through the wall and ceiling assemblies is essential if the assemblies are expected to prevent passage of heated gases and smoke. The most commonly used methods for protection of openings are automatic or self-closing fire doors, fire windows, fire resistive shafts and fire dampers in air ducts. Building codes permit use of water spray systems and sprinkler systems combined with exhaust systems or curtain boards[1] as alternatives for protection of some openings.

The purpose of this report is to review code requirements concerning these alternative methods of protection and to review the available literature concerning any experimental work which serves as design bases for these systems. Further experimental work is planned by the Center for Fire Research at the National Bureau of Standards (NBS). A description of the NBS facility for this work is also provided in this report.

2. PURPOSE

Reliable fire protection for openings through fire resistive construction assemblies is essential if the assemblies themselves are to serve their purpose. Failure to prevent passage of heat and combustion gases through openings can result in uncontrolled fire spread throughout the building, thereby jeopardizing the safe means of egress for building occupants. In effect, the value of all essential fire resistive barriers may be seriously compromised if openings are not protected. This report assesses the provisions of the codes which permit sprinkler and curtain board, sprinkler-vent, and spray nozzle methods, and it reviews previous experimental work which addresses these methods of protection.

3. EXISTING CODES AND STANDARDS

A literature survey of nationally used standards and building codes reveals that alternative methods are specifically permitted for enclosing escalators and stairways. These codes and standards are individually examined and referenced later in this section. The methods basically consist of the following:

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[1]A curtain board is a rigid noncombustible screen hung from a ceiling to block convective heat flow across a ceiling.

a. Sprinkler-curtain board method. Sprinklers and curtain boards at the ceiling are located around the perimeter of the opening (see figure 1). The purpose of this method is to direct the flow of hot fire gases across the ceiling at the draft curtain so that the sprinklers will activate along the perimeter of the opening and limit the heat flow upward to the next floor.

b. Sprinkler-vent method. This method consists of open sprinklers or spray nozzles around the perimeter of the opening. Water flow to sprinklers is controlled by a heat actuated valve. An exhaust system is also installed with inlets around the perimeter of the opening at the ceiling. At the top of the open shaft an inlet is provided for makeup air. The concept is to establish a water curtain around the opening to reduce the transmission of heat while the exhaust system operates only on the fire floor to remove combustion gases before they spread to other floors (see figure 2).

c. Spray nozzle method. This method uses conical shaped spray nozzles which are located in the opening and directed downward through vertical openings. The purpose of this method is to cool the heated gases entering the opening and also to develop air flows in the stairwell to prevent the upward passage of convected heat. The high velocity nozzles tend to entrain air to a greater intent than standard sprinklers. With this capability the spray can induce air flow to counter or reverse the flow of hot gases from a fire on the lower level. Draft curtains are installed around the opening to enhance the counter flow action of the nozzles (see figure 3).

The survey of codes and standards indicates that for escalator openings through floor-ceilings, these methods are permitted as alternates to a complete fire-rated enclosure. In general, the alternate methods are only permitted if the escalator or stairway does not serve as a required exit and if the building or at least the interconnected floors are protected completely with automatic sprinkler systems. The codes and standards vary greatly, however, in which method is permitted. The Life Safety Code (NFPA 101) [1][2]

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[2]Numbers in brackets refer to literature references at the end of this paper.

permits use of either sprinkler-vent method or spray nozzle method for escalator openings. Specific design parameters are established for flow rate of sprinklers, nozzle pressures, orientation of spray nozzles, and flow rates for exhaust systems. By reference to NFPA 13, Standard for Installation of Sprinkler Systems [2], NFPA 101 also recognizes the sprinkler-curtain board method detailed in NFPA 13 (see figure 1).

Model building codes recognize sprinkler-vent and spray nozzle methods as alternate protection for some openings in fire resistive assemblies. The BOCA Basic Building Code [3] permits use of the sprinkler-vent method, basically as described in the Life Safety Code for both escalator and open supplemental stairways not included as a required exit way. The occupancy types in which this method can be used, however, are more limited. The sprinkler-vent method cannot be used in what the code classifies as Group A-4 and I occupancies. These include schools and institutional occupancies (hospitals and nursing homes).

The Uniform Building Code [4] recognizes only the sprinkler-curtain board method as an alternate to enclosure of escalators in what it calls Group B occupancies, i.e., office, industrial, mercantile and storage buildings. The design parameters vary from those in NFPA 13 in that the depth of the required draft curtain is less (12 in from ceiling) and there are no water flow density requirements. (See table 1 for summary of design requirements.)

The National Building Code [5] permits only the sprinkler-curtain board method as an alternative to enclosure of escalators. No occupancy restrictions are stated. The design requirements are equivalent to those in NFPA 13.

The Standard Building Code [6] refers to the American Safety Code for Elevators, Dumbwaiters, Escalators and Moving Walks, ANSI A.17.1 [7], for alternative methods to the enclosing of escalators. This standard recognizes the sprinkler-curtain board method, a variation of the sprinkler-vent method, and the spray nozzle method as alternatives. The sprinkler-curtain board is described basically the same as NFPA 13; however, no specific guidance is given for water flow densities and spacing of sprinklers. The code has a unique requirement that in buildings of 1415 m^3 (50 000 ft^3) or less it is recommended that the sprinkler-curtain board method be supplemented by an automatically controlled exhaust system to create a down draft through the opening. No design specifications are given for this method. The code also recognizes by direct reference the spray nozzle method as described in the Life Safety Code (NFPA 101).

One large city code, the Chicago Building Code [8] was also examined for the alternatives to escalator enclosures. This code permits escalators which are not required as a means of exit to be unenclosed if "effective means are provided which will prevent the spread of fire or gases from one floor to another in the event of fire". By this statement it is inferred that any of the previously mentioned systems are acceptable. This code differs from previously mentioned model codes and standards in that no specific requirements for sprinklers in other parts of the building are mentioned in relation to this provision. Table 1 summarizes the provisions of the codes and standards concerning the alternate methods of protection for stairways and escalators.

In addition to stairways and escalators, spray nozzle methods for protecting openings through fire walls and fire resistive floors for conveyors or other mechanical material movement are contained in the NFPA Fire Protection Handbook [9] and the Factory Mutual Handbook of Industrial Loss Prevention [10]. Specific design criteria are contained in these references including nozzle types, location, orientation, flow densities, nozzle pressures and arrangement of draft boards. Figures 4 and 5, taken from the references, illustrate this type of protection for horizontal and vertical openings.

The Minimum Property Standards (MPS) of the U.S. Department of Housing and Urban Development (HUD) for multifamily [11] and care type [12] housing require automatic sprinklers in corridors. The requirements apply to multifamily structures four stories or more in height and care type housing of fire resistive or noncombustible construction regardless of height. The purpose of the requirement is to prevent a fire originating in an apartment from spreading along a corridor past an adjacent apartment entrance door. The sprinkler system is intended to limit the rise in temperature in the corridor, and to permit use of the corridor as an exit.

4. PREVIOUS RESEARCH WORK

A survey was also made of the available sources of information on research work which developed data bases for the alternate methods permitted in the codes. The most extensive experimental work was conducted by the Grinnell Automatic Sprinkler Corporation in cooperation with Westinghouse and Otis Elevator Corporations in 1945 and 1946. Results of this fire test program are contained in an unpublished report provided by the Grinnell Corporation [13]. Over 40 full-scale fire tests were conducted to determine empirically the essential design parameters needed to prevent heat and smoke from passing from one floor to another through an escalator opening. The fire energy sources for the test series consisted of pans of alcohol ranging in area from 1.4 to 3.5 m^2 (15 to 38 ft^2). Smoke was produced by smoke bombs and oil soaked cellulosic materials. The fires were allowed to burn uncontrolled and there was no attempt to extinguish fires while the fire protection systems for the escalator opening were being evaluated. Two basic concepts were examined, namely, spray nozzle and sprinkler-vent methods. Various design parameters were tested including nozzle types, pressures, orientations, flow densities, exhaust system arrangements and flow rates. Orientation refers to the location and direction of the nozzles relative to escalator and surrounding construction. Test results indicated that five nozzles with conical shaped spray patterns operating at a nozzle pressure of 172 k Pa (25 lbs/in^2) and with total flow of 341 ℓ/min (90 gal/min) were able to create down draft effects sufficient to counter the buoyancy forces of hot gases from fire below. Fire nozzles were located in the soffit of the escalator opening. Essentially, a local pressure differential was established between the first and second floors in the vicinity of the escalator. The report emphasized the importance of nozzle location and direction, flow rate and nozzle pressure for the optimum down draft effect. Eventually, the higher buoyancy forces at the first floor level from the 3.5 m^2 (38 ft^2) alcohol fire overcame the downward air currents and forced some smoke up. Quantitative values for the smoke density or concentration of combustion gases were not reported. Apparently the program objective was to develop a system which completely blocked the passage of any visible smoke, and there was no attempt to determine if the quantities of smoke passing through the water spray reached levels to limit human tenability in the upper floor areas. At this stage in the project an exhaust system was introduced in combination with both spray nozzles in the opening and later open sprinklers were added to form a curtain around the perimeter of the opening (sprinkler-vent method). The optimum arrangement and flow rate consisted of a duct with slotted inlets installed around the escalator opening at the first floor ceiling. The exhaust system provided an average air velocity of 91.5 m/min (300 ft/min) down through the opening. Makeup air was provided at the top level of the escalator opening.

Similar full-scale fire tests were conducted by Thompson at the Factory Mutual Laboratories (FM) to develop spray nozzle methods for protecting conveyor openings [14]. Thompson noted that results of the experimental work indicated that high air movements were created by commercial spray nozzles with a high velocity, cone shaped discharge consisting of a high concentration of water droplets. At 50 psi nozzle pressure, nozzles of 8 mm (5/16 in) diameter produced a free air movement of approximately 226 m^3/min

(8000 ft^3/min), while 9.5 mm (3/8 in) diam nozzles generated around 283 m^3/min (10 000 ft^3/min), 12.5 mm (1/2 in) diam nozzles around 368 m^3/min (13 000 ft^3/min), and 20 mm (3/4 in) diam nozzles around 509 m^3/min (18 000 ft^3/min). There was no reference provided for this data. Results of this experimental work prompted Factory Mutual Laboratories to study the feasibility of using spray nozzles to protect openings through fire walls and floors for conveyor systems. Such openings are commonly protected with fire doors but such doors, even if closed, may permit the passage of considerable heat and smoke while nominally maintaining their integrity according to the test requirements. Results of FM tests indicated that it was possible to counter the flow of heated gases through an 2.4 x 2.4 m (8 x 8 ft) wall opening with four spray nozzles with 9.5 m (3/8 in) orifices directed toward the opening. Nozzles were placed in a tunnel with cross sectional dimensions of 2.4 x 2.4 m (8 x 8 ft) and heated gases were produced with gasoline pan fires located in a burn room adjacent to one end of the tunnel. At the opposite end of the 4.9 m (16 ft) long tunnel an exhaust fan created a draft in the tunnel and increased the convective heat flow from the burn room. (See figure 6 for temperature reduction relative to varying nozzle pressures and air flow rates.) Exposure side temperatures were measured at the entrance to the burn room and were varied by relocating the gasoline pan fire around the burn room relative to the opening into the tunnel. The pans varied from 1.4 to 3.3 m^2 (15 to 36 ft^2) in area. Tunnel air flow rates were varied by changing the fan speed. Data from approximately 16 tests developed the performance curves shown in figure 6. The tests indicated that the position of the nozzles and the shape of the spray cone were important design considerations to insure optimum coverage of the opening with the water spray. Thompson noted that, by themselves, "ordinary" sprinklers, designed to provide a curtain over the doorway, were not effective in countering the flow of hot gases through the opening. No further details, including air flow rates or design details, were provided for the sprinklers used. The "ordinary" sprinklers used in those experiments were old style sprinklers which were designed to project water above, as well as below, the sprinkler. A spray nozzle method of protection for a 1.2 x 2.1 m (4 x 7 ft) opening through a ceiling was also examined. Two 12.5 mm (1/2 in) diam orifice spray nozzles operating at 172 k Pa (25 lb/in^2) nozzle pressures placed above the opening and directed downward through a 6 ft deep draft tunnel (4 x 7 ft area of opening) were effective in reversing the flow of heat and smoke (see figure 5). Two "ordinary" sprinklers placed just below the roof of the opening were ineffective in countering the flow, even at nozzle pressures of 517 k Pa (75 lb/in^2). Thompson included some important observations which must be considered in use of the spray nozzle systems. The pressure from the spray nozzle system forced air from the protected area into the fire area, and it might also force hot gases and smoke from the fire area through any other openings. Openings to other areas must be protected and openings to the exterior of the building may be essential to vent the combustion gases. A flow density of 81.5 to 163 $\ell/min/m^2$ (2 to 4 $gal/min/ft^2$) was recommended for wall and ceiling openings with the same areas used in this project.

An essential feature of any water spray system in protection of the openings is the ability of the spray to prevent transmission of radiant and convective heat energy. Heselden and Hinkley measured the transmission of radiant heat energy through water sprays from a flat spray nozzle[3] and a standard pendant sprinkler [15]. They demonstrated experimentally that the transmission of radiant heat energy was reduced as the flow rate per unit width of opening (or as the nozzle pressure) was increased (see figure 7). In their paper, reference is made to work by Schuler who demonstrated that increased nozzle pressure which creates smaller size water droplets reduced the transmission of radiant energy at constant water flows [16] (see figure 8). Heselden and Hinkley concluded that with the proper nozzles, i.e., properly designed flow and nozzle pressure, a water curtain capable of absorbing a large fraction of the radiant heat could be produced from flows comparable to typical sprinkler installations.

Based on the requirements contained in the HUD Minimum Property Standards [11,12], a research project was initiated at the Center for Fire Research to evaluate those criteria and to recommend improved designs for corridor sprinkler systems. In a report by Liu [17] the results of theoretical and experimental investigations were given concerning the effects of a corridor sprinkler system on the cooling and suppression of a fire in an adjacent apartment connected by an open doorway. The full-scale and reduced scale model tests showed that the water spray produced by ceiling-mounted sprinkler heads in the corridor was effective in reducing gas temperatures in the corridor to a level low enough for safe passage. Both the theoretical and experimental work showed that for the purpose of cooling heated gases, a spray with a large droplet diameter (larger than 0.5 mm) was not efficient. The report further concluded that a smaller orifice sprinkler which produces a smaller mean droplet size at the same water flow rate was more effective in both the cooling of the combustion products and in reducing the burning rate of the fuel.

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[3] A flat spray-sprinkler has a paraboloid water distribution directed towards the ground for a definite protection area, while some of the water sprays the ceiling.

5. SUMMARY ANALYSIS AND DISCUSSION

It is apparent that codes and standards differ considerably concerning acceptance of the sprinkler and spray nozzle methods of protecting openings. The types of acceptable systems, the degree of engineering design guidance and the applicability of these systems to types of buildings are all considered differently in the national codes and standards examined. The only position common to all national codes reviewed is that the systems can be used only for escalators which are not required exit ways and systems can be used only where buildings are fully sprinklered. The current situation in the codes clearly indicates a lack of confidence in these systems by the code-making officials. In prescribing a fully sprinklered building, it is assumed that a fire would be controlled by the sprinkler system before serious exposure to any openings through fire-resistive assemblies could occur (except possibly for fires directly under the opening in the short time before sprinkler operation). Therefore, the role of fire protected openings in walls and ceilings is much less significant than in buildings without automatic sprinklers. Design parameters established in NFPA 101 for the sprinkler vent and spray nozzle methods appear to be based on the work done by Grinnell Corporation [13]. Variations of the sprinkler vent methods permitted in the BOCA Basic Building Code [3] and in ANSI A.17.1 [7] are not based on any experimental work as far as could be determined by the survey for this report. The sprinkler-curtain board method is the most widely accepted approach among the codes surveyed. Also, it is apparently not based directly on any research work. The incorporation of a draft curtain around the opening simply insures operation of the sprinklers near the curtain before sprinklers operate on the floor above.

The work done by Thompson [12] served as the basis for the spray nozzle methods used for protection of conveyor openings contained in the Fire Protection Handbook [9] and Handbook of Industrial Loss Prevention [10]. The survey of the codes and standards indicated that there has been no further accepted applications of his work for the protection of other types of openings such as stairways and passageways through wall assemblies.

The full-scale fire tests conducted by Grinnell and FM examined the capabilities of these systems against selected uncontrolled heat sources. The work empirically developed suitable systems incorporating sprinkler-vent and spray nozzle methods for countering the flow of hot gases from the uncontrolled energy sources. The codes and standards, however, generally do not recognize these systems in unsprinklered buildings as alternatives to fire resistive enclosures of stairways.

heat flux and oxygen depletion will be considered. With the spray nozzle protection scheme, the depth of curtain boards will be varied to study the effect on cooling. The instrumentation will record the percent reduction in heat flow, heat transfer and pressure differentials created by heat energy source and sprinkler and spray nozzles. The primary function of these tests will be to measure temperature and gas flow into the stairway at selected levels of water flow and nozzle pressure of the sprinklers and spray nozzles.

It is expected on the basis of previous work that the systems will not totally prevent passage of combustion products. However, with an optimum system design, the quantity of products which escape through the opening may be sufficiently restricted to maintain a tenable environment for persons on upper floors.

7. CONCLUSIONS

A survey of nationally used standards and model building codes revealed that there are varying provisions among these references concerning sprinkler and spray nozzle methods of protecting openings in fire resistive assemblies. Most of these references restrict use of these alternate methods to protection of escalator openings through floors of fully sprinklered buildings only. However, the limited research work in this subject area indicates the following:

a. Flow of heat from a free burning fire through horizontal and vertical openings can be reduced by spray from an automatic sprinkler or spray nozzle.

b. Small droplet size in the spray is important in reducing transmission of radiant heat energy and in cooling hot gases and subsequently reducing the buoyant forces of convective heat flow. (There is a limiting size, however, where droplets which are too small and too few are carried away by the fire and the buoyant forces and will not prevent the passage of heated gases.) For a given flow rate, higher nozzle pressures produce smaller diameter droplets than lower nozzle pressures. This provides more efficient cooling of the heated gases.

c. Air entrainment in the spray also acts to counter buoyant forces in convective heat flow. Higher nozzle pressures for a given flow rate also creates greater air movement than lower nozzle pressures at the same flow rate.

d. The air movement from a spray nozzle system can be increased by directing the nozzle into a partial enclosure surrounding the opening (see figure 5).

Most of the previous experimental work was conducted about 30 years ago and the data did not include measurements of the mass flow rate of air through the openings. In the planned research work, this rate will be measured as a function of nozzle flow rates, pressures and orientations, so that design parameters can be established for these sytems. Performance curves will be developed for the sprinkler and nozzle systems. Tenability levels will be considered in establishing these parameters whereby a fire protection engineering designer could establish a quantitative value to the protection method and incorporate it into an overall fire safety model or system for the building. By refining the previous experimental work with modern sprinkler and spray nozzles and by clarifying the engineering design parameters for these systems, the experimental work has the following objectives:

a. To provide codes and standards making groups the needed technical input to improve the guidance contained in their documents.

b. To enhance more widespread acceptance and use of these systems particularly in unsprinklered buildings.

c. To provide more flexibility in the design of fire protected enclosures, stairways and vertical openings.

8. ACKNOWLEDGMENTS

The author extends appreciation to Mr. Philip Merdinyen of the Grinnell Fire Protection Systems Company, Inc. and the staff of the Factory Mutual Research Library who provided valuable information on earlier fire tests conducted by their respective organizations.

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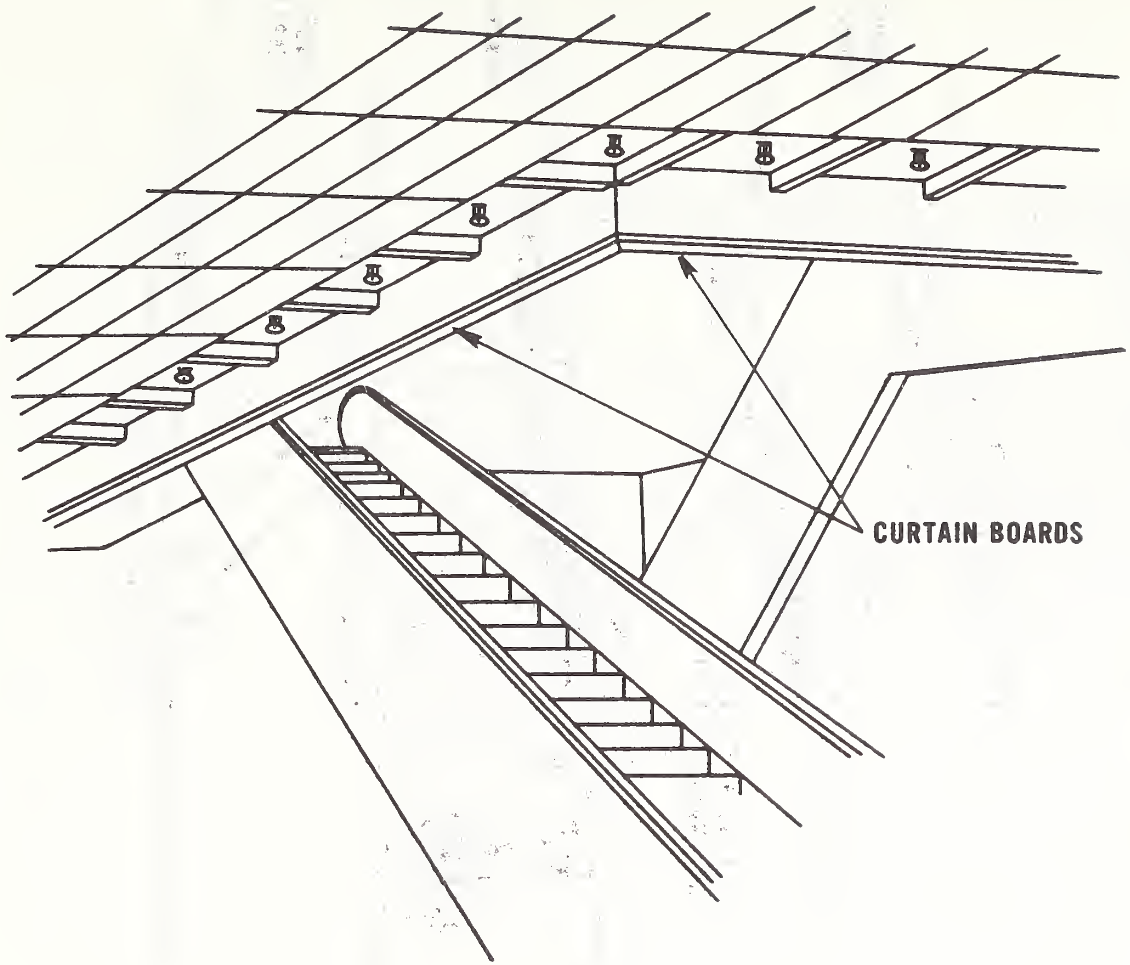


Figure 1. Sprinkler-curtain board method [2]

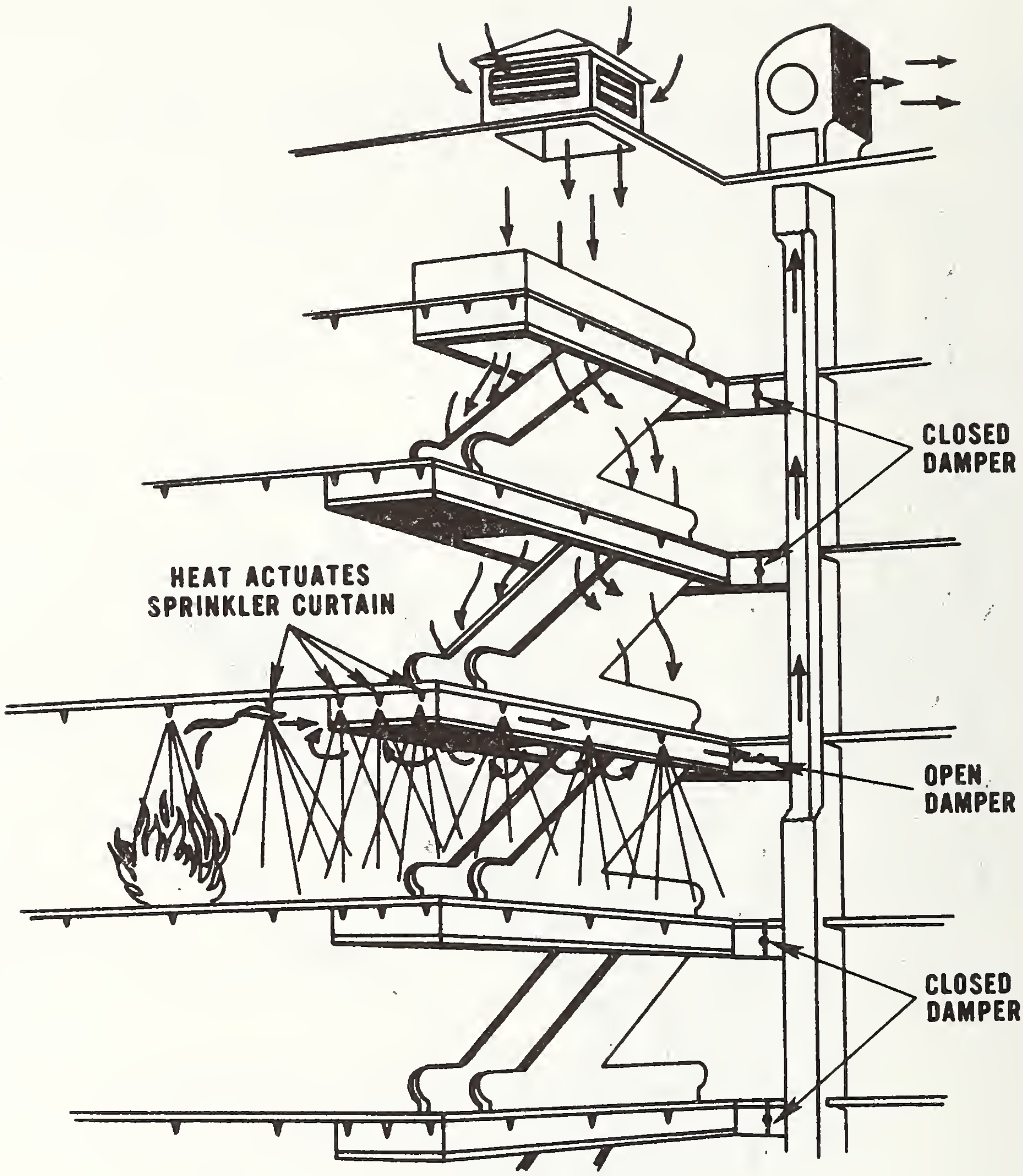


Figure 2. Sprinkler-vent method [11]

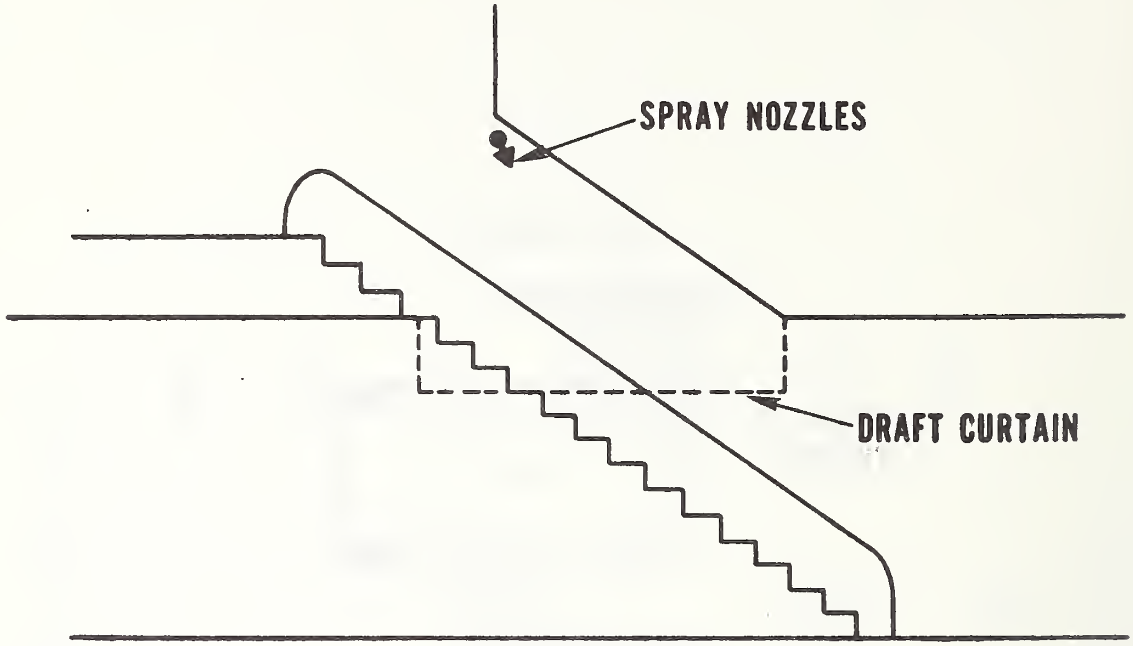


Figure 3. Spray nozzle method for protection of escalators

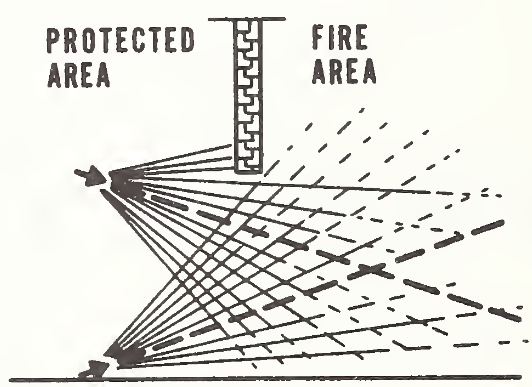


Figure 4. Spray nozzle method for protection of fire wall conveyor openings [9]

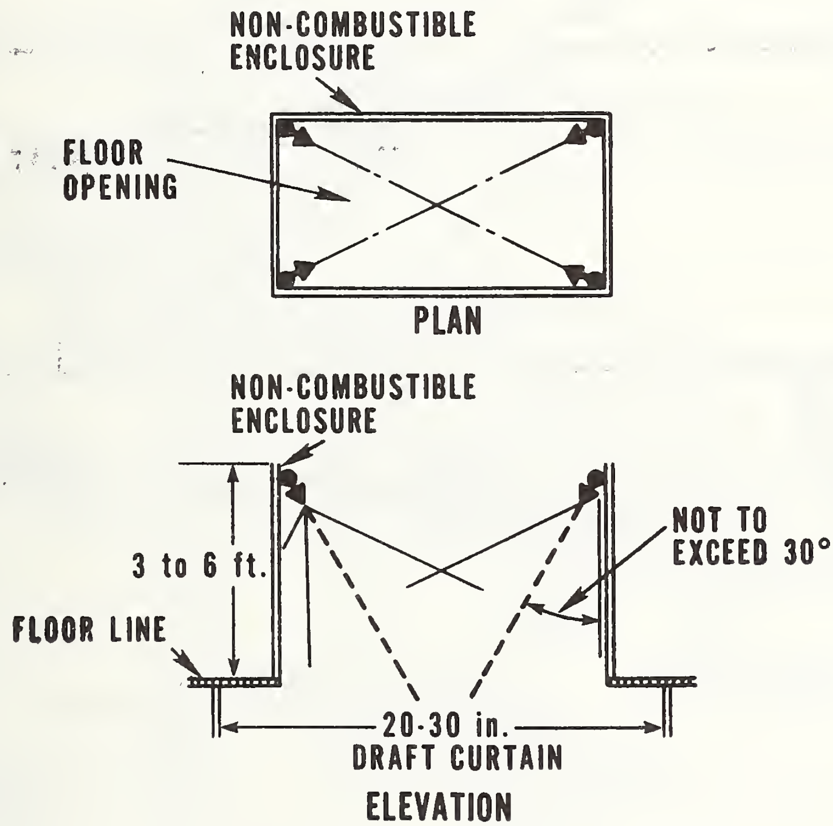


Figure 5. Spray nozzle method for protection of floor/ceiling conveyor openings [9]

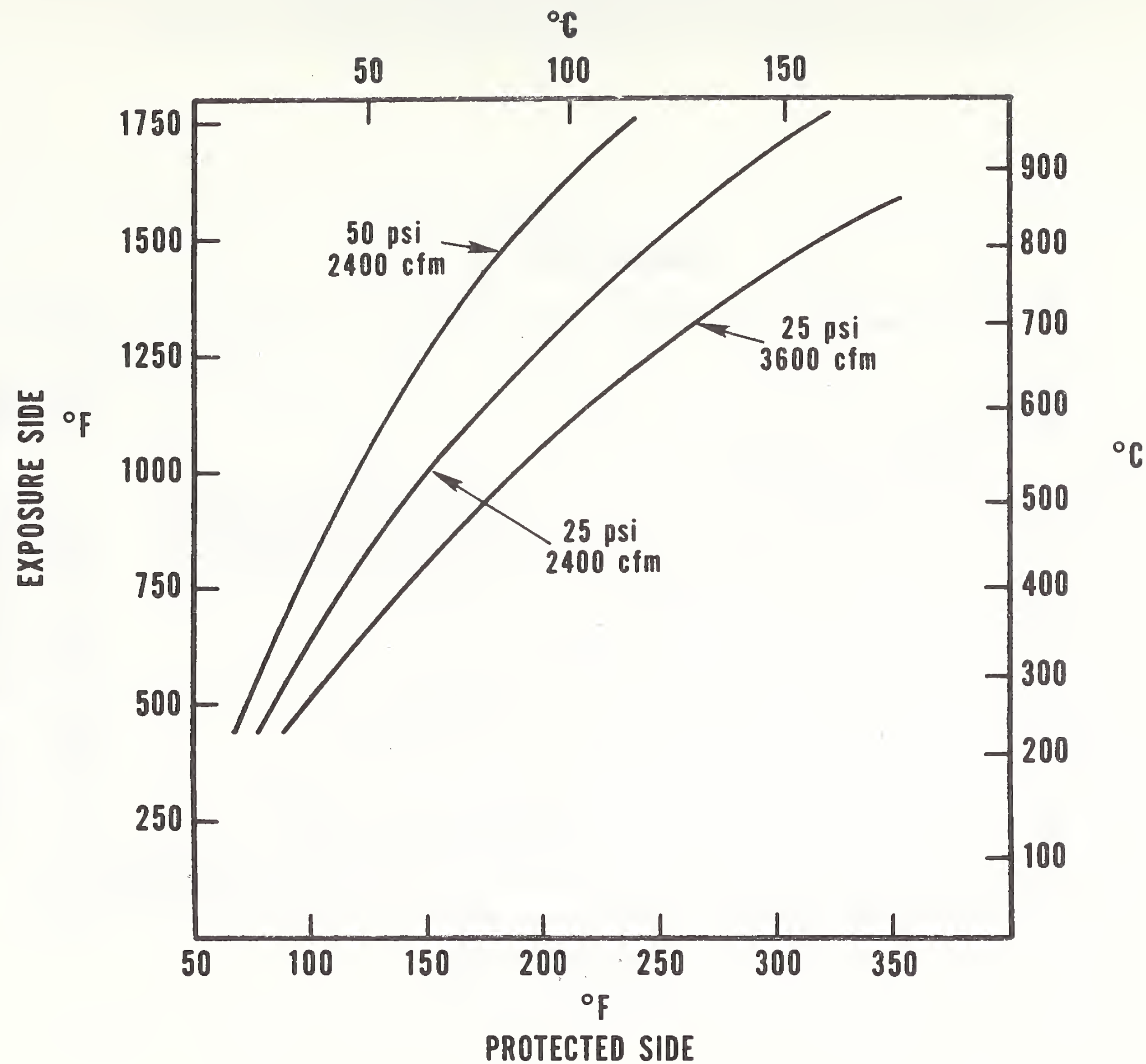


Figure 6. Temperature differential - spray nozzle system in wall openings [14]

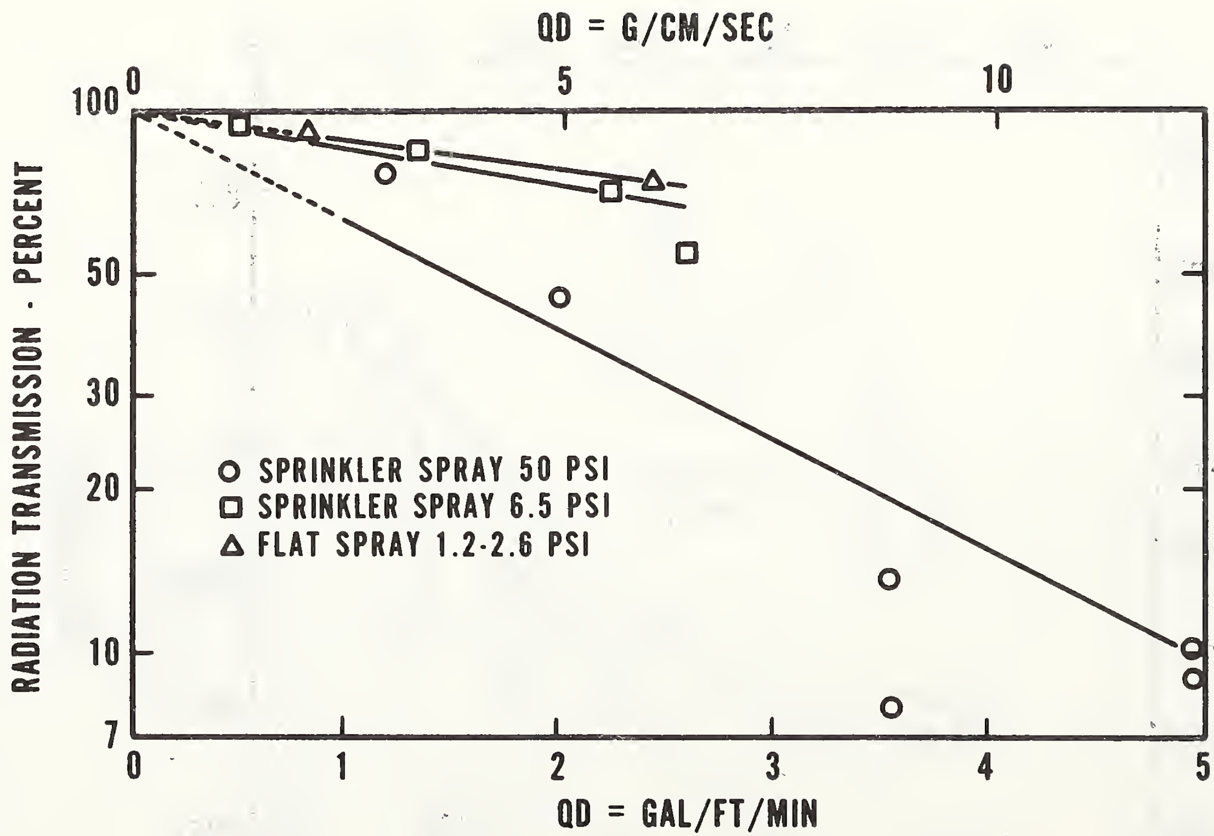
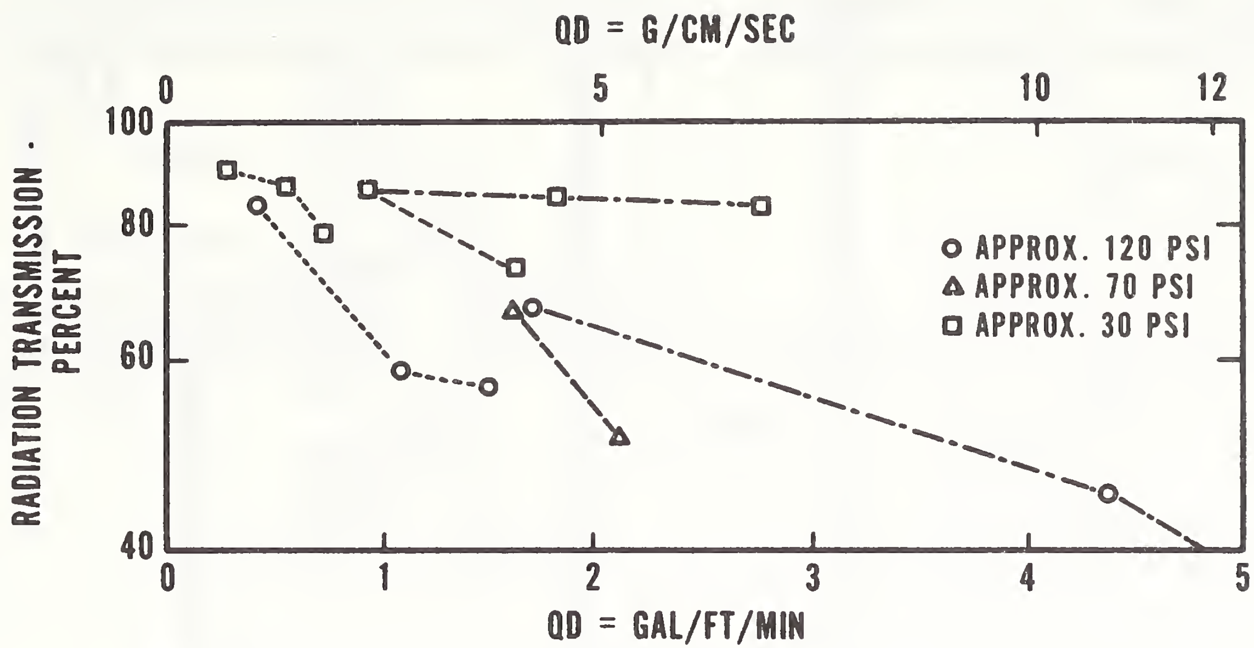


Figure 7. Effect of water pressure on the amount of radiant heat absorbed by water sprays [15]



NOZZLE DETAILS (TYPE AND FLOW CHARACTERISTICS)

---- Sprinkler; 82 dm^3/min at 1 bar (21.5 gal/min at 15 lb/in^2)
— — — Water curtain nozzle; 120° pattern; 36 dm^3/min at 1 bar (9.5 gal/min at 15 lb/in^2)
------ Water curtain nozzle; 120° pattern; 33 dm^3/min at 1 bar (9 gal/min at 15 lb/in^2)

Figure 8. Effect of water pressure on the amount of radiant heat absorbed by water spray [16]

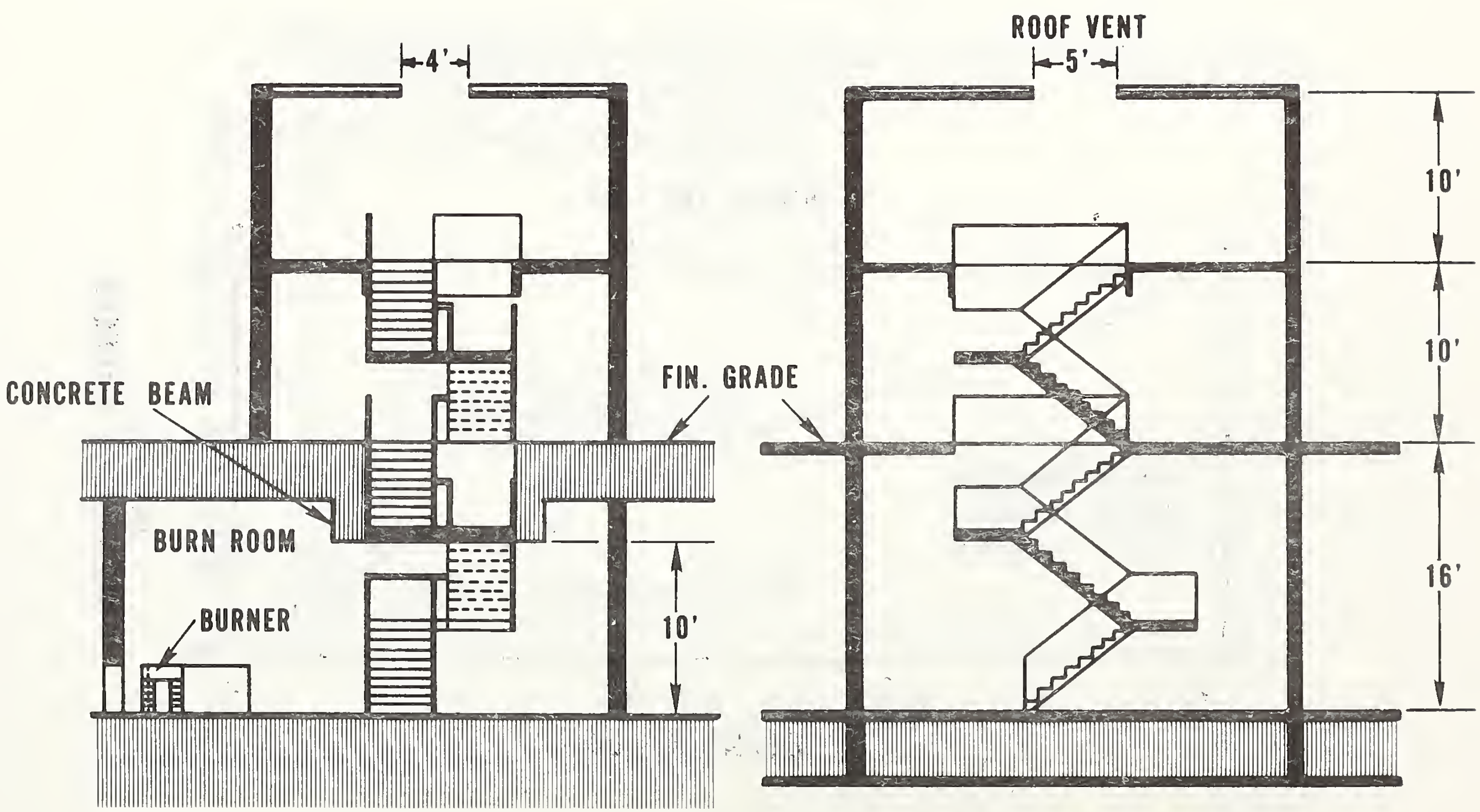


Figure 9. NBS open stair fire test facility

Table 1. Comparison of codes and standards - sprinkler, spray methods for protection of openings

Reference	Type of* System	Type of Opening	Occupancy Restrictions	General Requirement for Sprinklers	Design Requirements
Life Safety Code	1	Escalator	No	Yes	References NFPA 13
	2	Escalator	No	Yes	Exhaust must produce 300 ft/min through opening. Open sprinklers controlled by auto valve w/flow density of 3 gal/min/ft
	3	Escalator	No	Yes	Flow density of 2 gal/min/ft^2, 25 psi nozzle pressure; nozzle orientation; draft curtain - 20 in
NFPA 13 Sprinkler Standard	1	Escalator	No	Yes	Closed sprinklers 6 ft, centers, min flow per sprinkler: 15 gal/min, density: 3 gal/min/ft, draft curtain 18 in below sprinkler
BOCA Basic Building Code	Variation of 1 & 2	Escalator & Supplemental Stairs	Yes	Yes	Draft curtain 18 in below ceiling, closed sprinklers, 6 ft centers; exhaust system
Uniform Building Code	1	Escalator	Yes	Yes	Draft curtain 12 in from ceiling; closed sprinklers 6 ft centers - no flow requirements
National Building Code	1	Escalator	No	Yes	Same as NFPA 13
Standard Bldg. Code					References ANSI A17.1
ANSI A17.1	Variation of 1 & 2	Escalator	No	Yes	Draft board 6 in below sprinklers. If building volume $\leq$ 50 000 ft^3, provide automatic exhaust (no design specified)
	3	Escalator	No	Yes	References Life Safety Code
Chicago Building Code	-	Escalator	No	No	None-refers only to "effective means" to be used when escalators are not enclosed

* 1. Sprinkler-curtain board; 2. Sprinkler-vent; 3. Spray nozzle

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15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.*)

A review of literature was conducted to determine the state-of-the-art of automatic sprinkler, sprinkler-vent and spray nozzle methods of protecting openings in fire resistive assemblies. A review of nationally used model building codes and standards indicated that they have varying provisions for these types of systems. Generally, the use of these systems is only applied to escalator openings in fully sprinklered buildings. Previous experimental work, however, demonstrated that these systems can also be effective in preventing passage of heat and smoke through other types of openings in structural assemblies.

An outline of a planned research project and a description of the test facility are given. The project will develop design parameters for sprinkler-vent and spray nozzle methods for protecting stairways and other openings through floor ceiling assemblies. Results from this project may suggest improvements to current codes and standards involving these systems and possibly permit their wider use in unsprinklered buildings.

17. KEY WORDS (*six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons*)

Automatic sprinkler; building code; smoke movement; spray nozzle; stairway protection; ventilated stair

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