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Papers presented at the Symposium on . . .

DESIGN CONSIDERATIONS FOR FIRE SAFETY

AT THE SEMIANNUAL MEETING OF THE

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

January 24-28, 1971 • Philadelphia, Pennsylvania

Published by the
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FIRE HAZARDS IN BUILDING

From the Symposium presented at the ASHRAE Semiannual Meeting, January 19-22, 1970, San Francisco, California. **CONTENTS:** Building Code Requirements for Air-Handling Systems, by R. G. Sandvik; Factors in Controlling Smoke in High Buildings, by J. H. McGuire, G. T. Tamura and A. G. Wilson; Air-Handling Systems for Control of Smoke Movement, by G. T. Tamura, J. H. McGuire and A. G. Wilson; Relating Air-Handling Requirements in Fire Codes and Standards to Fire Safety in Buildings, by H. E. Nelson; Fire and Smoke Detection Systems, by D. A. Diehl; Research Needs in Fire and Smoke Control, by I. A. Benjamin.

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FIRE HAZARDS IN BUILDINGS AND AIR-HANDLING SYSTEMS

From the Symposium presented at the ASHRAE Annual Meeting, June 24-26, 1968, Lake Placid, New York. **CONTENTS:** Principles of Fire Protection by G. A. Pelletier; Building Mechanical Systems and Fire Problems (Part I), by H. E. Nelson; Building Mechanical Systems and Fire Problems (Part II), by F. Andrews, Jr.; Problems in Applying NFPA Standard 90A, by M. M. Brown; Protection of Duct Openings in Fire Resistive Construction, by B. A. Zimmer; Protection of Duct Penetration in a Fire Resistive Ceiling, by J. C. Ollinger; Smoke Problems in High-Rise Buildings, by N. B. Hutcheon and G. W. Shorter; Manufacturers' Responsibility to Furnish Fire-Safe Duct and Insulating Materials, by W. B. Silk; Summing Up, by A. G. Simmonds and C. W. Phillips.

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ABSTRACTS

Chairmen — A.G. Wilson *Member ASHRAE* **W.A. Schmidt** *Member ASHRAE*

Current Status of Fire Testing Floor-Ceiling Assemblies with Duct Systems and Outlets

R.G. SANDVIK

While the floor-ceiling assemblies are normally tested by manufacturers of ceiling materials, the Acoustical & Insulation Materials Assn and the Sheet Metal Air Conditioning Contractors' National Assn have cooperated on a few tests of floor-ceiling assemblies to permit larger ceiling openings to accomodate today's air-conditioning systems. Through the testing and listing procedure, many manufacturers of ceiling materials have used 12-in. diameter ceiling outlets for the air handling system and thereby have, on listed assemblies, restricted the ceiling outlet to approximately 113 sq in./100 sq ft of ceiling space. A few have used outlets 18-in. in diameter and have thus restricted the diffuser opening sizes to 254 sq in./100 sq ft of ceiling area. Cooperative testing between the two Associations have made it possible for some ceiling assemblies to continue to be a "rated" floor-ceiling or roof-ceiling assembly with allowable opening sizes to 24 by 24 in. sq or a 576 sq in. opening for each 100 sq ft of ceiling area.

Smokeproof Enclosures

J.G. DEGENKOLB

The Life Safety Code, as published by the National Fire Protection Assn, describes a smokeproof enclosure as a stairway which is accessible via a vestibule open to the outside and on an exterior wall of a building. If this concept is followed literally, core type buildings could not be constructed unless a considerable area of the building was used to carry a corridor to an exterior wall and vestibule and stairway were placed just inside an exterior wall. This can be quite expensive. Fire tests were conducted in buildings ready for demolition in an attempt to learn how mechanical systems could accomplish the same purpose. The system discussed involves supply and exhaust ventilation for the vestibule so that a negative pressure is developed. The stairway itself is vented but pressurized.

Pamphlet 90A — Controls Section

A.P. ROBINSON, II
Associate Member ASHRAE

The technology involved in applying fire protection devices to air handling equipment utilizing ductwork systems is in its infancy. In both low- and high-rise buildings, there is a continuously growing concern regarding smoke inhalation and panic created from smoke situations. Pamphlet 90A suggests the application of devices to these systems to attempt to lessen the hazards. There is a general disagreement among building owners and design engineers and the National Fire Protection Assn as to the feasability of the pamphlet recommendations. In the case of the high-rise building, this disagreement generally results in little or no protection. Low-rise buildings are quite often overprotected which needlessly adds to their construction costs. This paper is an attempt to outline what can be done now, with available equipment, to existing buildings and to planned buildings to lessen possibility of loss of life due to smoke.

Smoke Control in High-Rise Buildings

J.B. SEMPLE
Member ASHRAE

Fire destroys property. Smoke is the killer of 80% of "fire victims." Fire codes and regulations have been dictated in the light of property loss risks to the extent that personal safety is often hardly considered and sometimes even exposed to greater hazards. Smoke from burning contemporary furnishing materials has greatly increased life hazards without appreciably increasing property risks, not only by multiplying obscurity, but also by releasing additional poisonous products of partial combustion. These death hazards have been recognized by the National Fire Protection Assn Life Safety Code, but only in respect to hospitals and nursing homes. Total evacuation of any high-rise building in a reasonably safe period of time is impossible, yet that is the only life safety provision required in current codes.

Can Sprinkler Systems Solve Building Code Problems?

E. J. REILLY

Automatic sprinkler systems for fire protection are discussed in terms of their relationship to building code problems. Construction costs, design for public safety, design flexibility, and codes developed by the National Fire Protection Assn are discussed. A number of installations are illustrated in the talk.

INTRODUCTION

Symposium Chairmen

A. G. WILSON
Member ASHRAE

W. A. SCHMIDT
Member ASHRAE

The first ASHRAE Symposium[1] on fire safety, held during the 1968 Annual Meeting, identified the importance of fire protection considerations for designers of air handling and other mechanical systems in buildings. It also revealed the fact that there has been little participation by mechanical designers in the formulation of fire safety requirements and that there has been little opportunity for them to become expert in principles of fire protection or to make a contribution toward improved design for fire safety. Following the first Symposium, therefore, a decision was taken to establish a new ASHRAE Technical Committee on Fire Safety to cover the "development, collation and dissemination of information (through technical program, research and ASHRAE GUIDE AND DATA BOOK activity) on the application, design and installation of environmental systems and components relative to requirements for protection of life and property from fire and smoke in buildings."

The new Technical Committee became active in the fall of 1969 and since that time has sponsored two symposiums: Fire Hazards in Buildings[2], and the present Symposium. The increasing interest of ASHRAE members in fire safety is clearly evident in the excellent attendance at both symposiums and in participation in discussion from the floor.

Designers are concerned about requirements related to hazards created by air handling systems, for example, requirements for fire dampers and other provisions of NFPA Standard 90 A. Some papers have dealt with these aspects. They have also expressed interest in the use of the air handling system to contribute to fire safety, particularly to control smoke concentrations in areas outside the immediate fire compartment. A number of the papers have therefore dealt with the mechanisms of smoke movement and systems of smoke control.

It is now recognized that the time needed for evacuation of high-rise buildings, or those with a very large plan area, is substantial and that in such buildings it may be practicable to evacuate occupants only in the immediate vicinity of the fire; that it is necessary to ensure a tenable atmosphere in routes of egress and in other parts of a building to be occupied during a fire. This is basically an environmental control problem. It is, therefore, one in which members of ASHRAE should be keenly interested. They should be able to make a major contribution to its solution.

REFERENCES

1. Symposium bulletin, Fire Hazards in Buildings and Air-Handling Systems, from the ASHRAE Annual Meeting, June 24-26, 1968, Lake Placid, N.Y.
2. Symposium bulletin, Fire Hazards in Buildings, from the ASHRAE Semiannual Meeting, January 19-22, 1970, San Francisco, Calif., published 1971.

CURRENT STATUS OF FIRE TESTING FLOOR/CEILING ASSEMBLIES WITH DUCT SYSTEMS AND OUTLETS

R. G. SANDVIK

The results of recent tests at the Underwriters' Laboratories (UL) in Northbrook, Ill., provide new data involving the potential fire hazard characteristics of air distribution systems located in floor/ceiling or roof/ceiling assemblies. Analysis of the test data indicates that thermal protection of ducts by using fibrous glass acoustical duct lining and "board protection," or protecting the duct in the area of the outlet by covering it with standard mineral wood insulation bats, will provide equivalent, or better, fire protection than the use of a fire damper above a ceiling outlet.

To properly evaluate the information that was gathered at this test, the difference between it and the test employed to evaluate fire dampers, must be recognized.

The UL 555 Test Procedure is used for testing fire dampers, and is similar to, and derived from, the basic Fire Door Test, American Society of Testing and Materials (ASTM) E-152.

The floor/ceiling assemblies are tested according to the procedure outlined in the standard "Fire Test of Building Construction and Materials," UL 263, which is basically the same test as ASTM E-119 or NFPA #254. Both the horizontal fire dampers and the floor/ceiling assemblies are tested in the same large scale, 180 sq ft, furnace. Both tests utilized the standard time temperature curve that requires furnace temperatures of 1700 F (926 C) at one hour, 1850 F (1010 C) at 2 hrs and 2000 F (1093 C) at 4 hrs.

It is important to establish the difference between the two tests. The floor/ceiling test (UL 263) evaluates the ability of a specific assembly to *retard the transmission of heat* during a specified period of time. The specific period of time (the hourly rating assigned to the ceiling material, e.g., 1 hr, 1½ hrs, 2 hrs, 3 hrs or 4 hrs) is that time that the assembly does not exceed the temperature limits set by the test procedure. The hourly rating assigned to the *assembly* is normally applied to the membrane ceiling material employed. This hourly classification reflects the fact that the particular assembly withstood the test for that particular period of time or, more generally, surpassed that period of time.

The fire damper tests (UL 555) tests the ability of a mechanical item to *inhibit flame penetration* during a predetermined time period, with no requirement or consideration of heat transmission.

The criteria of the floor/ceiling assembly test requires that during the fire endurance test the transmission of heat through the test construction shall not raise the temperature of its unexposed surface more than 250 F (130 C) above its initial temperature, and the transmission of heat through the protection shall not raise the average temperature of the structural steel system employed above 1000 F (538 C) at any one of the four sections, nor raise the temperature above 1200 F at any one of the measured points.

A fire damper is only required to stay in place during the fire test, and to *show no other visible through openings* than those provided for operating clearances that were visible when viewed on a plan perpendicular to the mounting plane prior to the test. Openings between blades, or blades and frame, shall not exceed ¾ in. during or after the fire endurance test and 1 in. during or after the hose stream test. All latching mechanisms, shafts, springs, interlocking damper blades, etc. shall remain engaged and secure during the fire exposure and hose stream test. In addition, mechanical tests are performed to assure closing reliability after dust loading and salt spray exposure.

When a fire damper is tested, it is subjected to a hose stream test immediately following the shut-down of the furnace. The hose stream provides a rapid cooling and generally creates a condition that causes the damper components to warp, sometimes beyond the limits allowable. Any visual gaps are then measured to determine whether or not they exceed the limits established for the test.

Fire dampers are not tested in ducts, or under any condition of air movement other than the slight negative operating pressure for which test furnaces are generally designed. UL 555 requires that the fire dampers be installed in a wall, or reinforced concrete floor slab, using a sleeve arrangement to provide means for attaching the ductwork on either side, leaving the fire damper independently installed in the fire partition or floor slab. The fire dampers must be firmly attached to the sleeve and the sleeve is allowed to extend a few inches beyond each side of the wall, or slab, to allow ductwork and retaining angles to be attached. The retaining angles are not fastened to the building structure – they must be allowed to move when the damper expands from the application of heat.

Generally speaking, fire dampers are labeled for 1½ hrs, although testing procedures do allow for a 1 hr, or a ¾ hr rating. The lesser time ratings compare to those used for fire doors.

The time rating that is given either the floor/ceiling or roof/ceiling assembly, or the fire dampers, is based upon the amount of time required to reach any one of the several limits as determined by the test procedure being used. In the case of floor/ceiling assemblies the temperatures are the limiting factors. When fire dampers are tested, the dimensions of the openings determine whether or not a rating will be allowed. The time of exposure without exceeding the dimensional limitations establishes the rating in hours.

To meet UL requirements, ceiling manufacturers generally use a conservative approach. Electric light fixtures are covered with insulating material, such as the ceiling board. To minimize the heat transfer through diffuser penetrations of the ceilings the minimum sized air openings are employed. Air handling ceiling outlet sizes are restricted, usually to 13 in. round drops, and insulated "Flapper Dampers" are installed in the duct over the outlet.

The Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) in cooperation with the

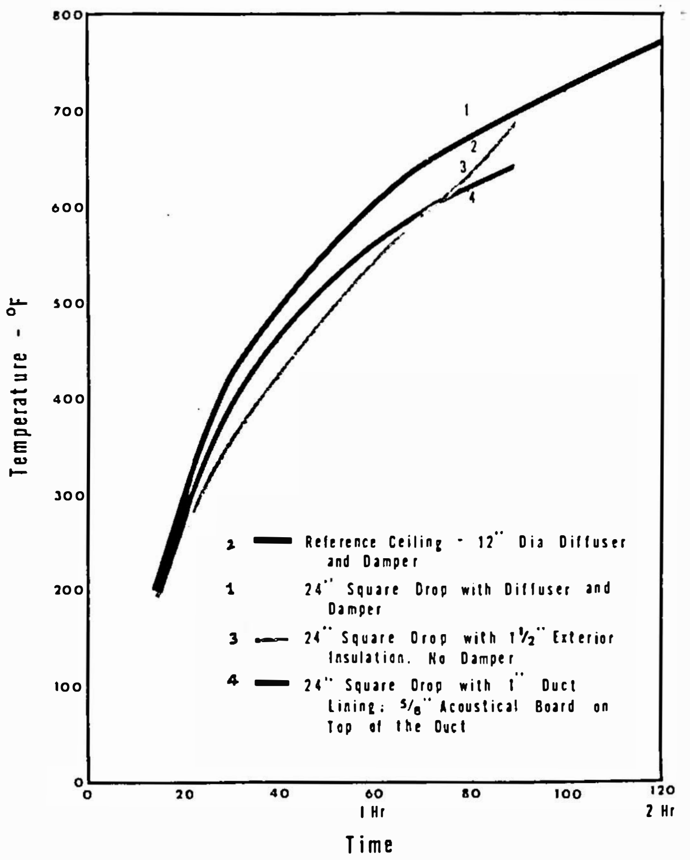

Fig. 1 Typical joist temperatures bottom chord

Acoustical and Insulation Materials Association (AIMA) has participated in the fire testing of a typical floor/ceiling assembly to provide substantiating data that would:

1. permit larger ceiling openings for air handling systems and
2. develop alternate methods of protecting the ceiling penetration in floor/ceiling fire rated assemblies.

The first test, sponsored by AIMA and co-sponsored by SMACNA, was performed early in January 1970 and compared a 24 in. X 24 in. ceiling diffuser to a 12 in. diameter ceiling diffuser. Fig. 1 gives a typical joist temperature reading at a comparative point for the two openings during the first 2 hrs of the test.

They were subjected to the same fire conditions in a split-frame test. In both outlets the assembly included a flat metal insulated damper that dropped over the top of the opening when a fusible link melted. The average temperature rise of the larger opening was within 5 to 10 min of the smaller opening during the entire test. Some floor/ceiling assemblies that withstood the UL 263 test for 10 or 15 min longer than the hourly rating assigned to it may qualify to use the larger opening, provided that other engineering adjustments have not reduced the extra time to a minimum.

A second test, sponsored by SMACNA and co-sponsored by AIMA, was undertaken in July of 1970 utilizing the identical floor/ceiling assembly, including the acoustical tile from the same manufactured lot as the January test. The purpose of the second test was to illustrate the effect of removing the "damper" protection used in the first test, and substituting a method of insulation, to provide or maintain the heat resistant qualities of the assembly.

Again a split frame assembly was used, dividing the 180 sq ft furnace into two sections of 90 sq ft each, in a fashion identical to the January test that employed "damper" protection. In the second test, with the damperless protection, both outlets were 24 in. X 24 in. The first test utilized plain steel duct without any acoustical treatment. In the second test, both openings were protected by insulating the duct above the openings for 4 ft, 2 ft each side of the center

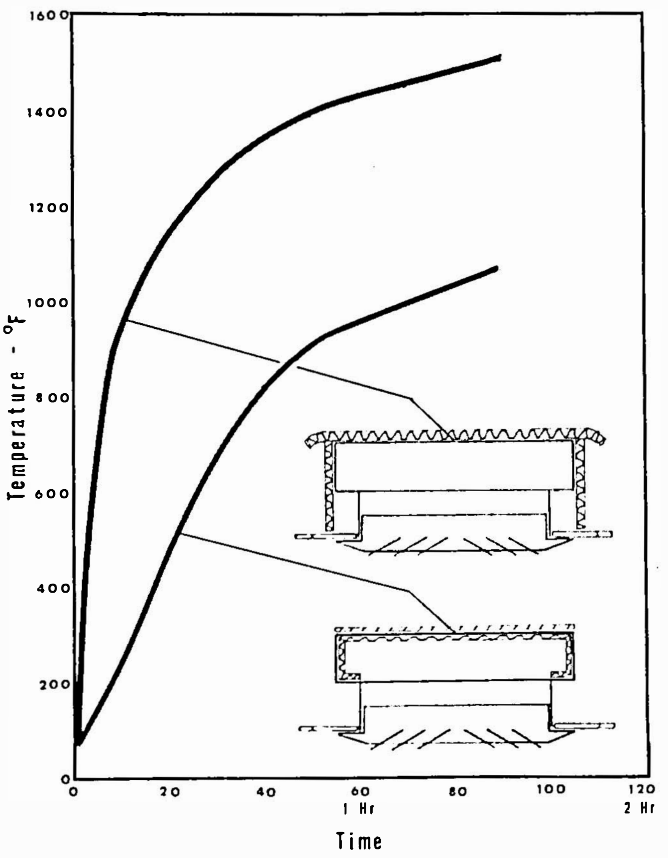

Fig. 2 Duct temperature above diffuser 24 in. drop – no damper

line of the opening. One side of the furnace utilized fibrous glass acoustical duct lining inside the duct, with acoustical ceiling board laid on top of the duct. The other side of the furnace used a plain steel duct with 4 ft of 1¼ in. thick mineral wool bats (a common wall insulating material) centered over the top of the opening, and extending a few inches on each side of the duct, supporting two vertical pieces of 1¼ in. thick mineral wood bats, that provided the protection on the side of the duct, from the top of the duct down to the top surface of the ceiling tile as illustrated in Fig. 2.

The heat transfer data, for these damperless forms of duct outlet protection, indicated that the assembly incorporating the fibrous glass acoustic duct lining with the addition of acoustical ceiling board on the top of the duct, developed slightly lower plenum temperatures throughout the 1½ hr duration of this test, than the assembly in the first test that utilized an insulated damper inside of the duct.

Unfortunately, the assembly that utilized the mineral wool bat protection for the duct outlet did not have the opportunity to perform as well as expected, due to a failure of the installing crew to properly fasten one channel supporting the tile ceiling.* The ceiling on this side opened within a few minutes after the test began and eventually dropped several ceiling tiles into the furnace. Despite this failure at the end of 95 min the plenum temperatures averaged well under 1000 F on both sides of the furnace. Temperatures on the unexposed surface were more than 100 F less than the allowable maximum temperature.

Directly above the center of each opening a thermocouple was placed on top of the steel duct, underneath the acoustical tile on one side, and underneath the mineral wool bat on the other side. While the temperature of the metal surface inside the duct that was unlined measured approximately 1500 F at 90 min, the temperature reading was about 1075 F at the same location on the other duct which was protected by the acoustical fiberglass duct lining. At this particular moment the fire in the furnace was registering about 1785 F. It appears that a fiberglass lined duct will, of itself, provide considerable fire protection. Temperature curves for these two thermocouples are illustrated in Fig. 2.

Historically, fire dampers have been required for many years. I believe NFPA Standard Codes as far back as 1927 call for fire dampers where a duct passed through a required fire partition. Obviously, early statistics from the fire reports showed that fire was traveling from one side of a required fire partition to the other where ducts pierced the partition. Fire reports did not indicate whether the fire went through the ducts, or around the ducts. The committee working on air conditioning obviously felt that these openings should be sealed up to protect the integrity of the partition, and added the requirement for fire dampers.

It may be that the fires went around the ducts rather than through the ducts, since most contractors would chop a hole through the wall large enough for their ductwork to pass through with "ample" clearance. Since the ductwork was to be concealed by a dropped ceiling and would not be visible after the acoustical ceiling was installed, they did not bother to seal the wall around the ducts. This condition would obviously greatly increase the danger of fire transmission across these walls.

For many years the only definition of a fire damper was an illustration that was shown in the NFPA 90A Code. Until 1957 any damper that resembled the illustration in 90A was accepted as a fire damper. In 1957 one damper manufacturer invested in an Underwriters' Laboratories test. A damper that he felt would pass the 1½ hr fire test E152 for fire doors, was tested and listed by the UL Listing and Inspection Service. Soon thereafter several other manufacturers also tested dampers and subscribed to the UL's Listing and Inspection Service to allow them to provide labeled fire dampers for the industry. The financial investment to cover the costs of the expensive testing required was passed on to the consumer of fire dampers, namely, the sheet metal contractor. In 1965 SMACNA undertook the testing of the fire damper that was illustrated in 90A. The first multiple blade fire damper failed the test. With some minor changes, such as utilizing stainless steel shafts and bronze bearings, other tests were performed with vertically mounted fire dampers until a multiple blade damper did pass the UL test. Drawings for these tested fire dampers were made available to the industry to provide sheet metal contractors with a tested fire damper that could be labeled and supplied on short notice. Since that time several manufacturers of fire dampers have designed more economical fire dampers and it has become "big business."

All tested fire dampers should be installed in a manner similar to their installation for the fire test, to insure their staying in position during the fire. Installation instructions are normally shipped with all fire dampers and alternate methods are illustrated in SMACNA's "Fire Damper Guide for Air Handling Systems." The basic fire hazard improvement appears to be the installation method, which seals the fire damper sleeve in the wall and yet allows room for the fire damper and the duct to expand under fire conditions, without leaving gaps for the fire to penetrate to the other side of the fire partition. Until recently all fire dampers were tested for 1½ hrs. One rationalization of this procedure expressed to me was that if the steel could withstand the temperatures required by the Standard Time Temperature Curve for 1½ hrs, steel dampers would, in all probability, provide protection for a somewhat longer period of time. There was no requirement for fire dampers to withstand a longer period of time because NFPA 90A only requires them in a 2-hr fire partition, requiring fire doors in 3 or 4 hr fire walls. Recently, one fire damper manufacturer had his fire damper tested for the 3 hrs, and is permitted to affix a Class A 3-hr fire door label to this damper. Technically, two of these "fire doors" installed in a duct will probably satisfy the test requirements of NFPA 90A for two Class A fire doors to be installed in a duct that pierces a 3 or 4 hr fire wall.

So much for fire dampers. Now let us consider floor/ceiling assemblies. Fire testing of floor/ceiling and roof/ceiling assemblies is intended to provide fire safety through horizontal compartmentalization in containing fires from spreading from floor to floor. Acoustical tile of a noncombustible nature is employed, not only to conceal the

**Another test of this assembly was performed after the January 1971 ASHRAE Meeting where this material was presented. The latest test was performed on February 26, 1971 and was apparently successful over a full 4 hour test period.*

structural members being utilized, but to protect the steel structural members from becoming heated beyond their failure point and, to insulate the floor above for a specific length of time. Originally tests were performed with cotton waste material on the floor above, and if the cotton waste material ignited, that ended the test and the rating allowed would depend upon the time lapse between the start of the fire and when the waste material ignited. This has been refined by the use of thermocouples and the current requirement is a maximum of 250 F deg temperature rise above the ambient temperature. Many air handling systems being used today utilize fibrous glass lined steel duct. This alone will provide considerable thermal protection to the floor/ceiling assembly if the test results of the recent SMACNA/AIMA UL Test are valid. Future tests, I am sure, will confirm this. Continuing testing of floor/ceiling assemblies which have means other than fire dampers to protect diffuser openings is presently under consideration.

In your design work you should be aware of the difference between the tests employed for floor/ceiling or roof/ceiling assemblies and those employed to test fire dampers. Hopefully, this presentation will help clarify some of the confusion that appears to exist as to what a fire damper is compared to a ceiling damper used for thermal protection.

SMOKEPROOF ENCLOSURES

JOHN G. DEGENKOLB

FEW fire protection requirements set forth in building codes have caused as much controversy as the requirement for smokeproof enclosures.

The term "smokeproof enclosure" describes a stairway designed to prevent quantities of smoke from entering the enclosure in such an amount as to make it untenable and unusable (Fig. 1). Historically, this has been accomplished by providing an intermediate vestibule between the building corridor and the stairway. The vestibule must necessarily be open to the outdoor air on at least one side so that smoke accumulations in the corridor

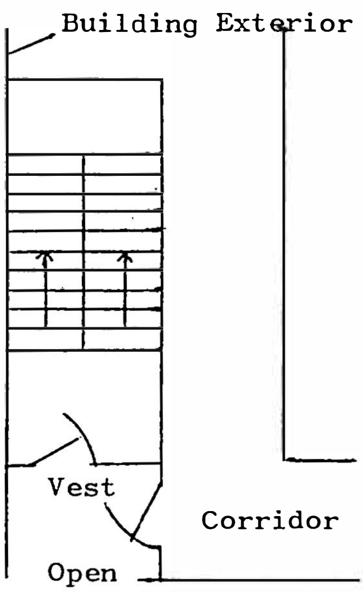

Fig. 1 Smokeproof Enclosure

will not move into the stair shaft to any considerable degree. Normally, about 50% of one side of the vestibule is to be open to the outdoor air. Both the Basic Building Code, and the Uniform Building Code call for a minimum opening of 16 sq ft. An alternate arrangement is to have the stairway accessible by way of a balcony.

The building codes recommended by the American Insurance Assn (the National Building Code) and the Southern Standard Building Code do not require smokeproof enclosures, smoke towers, smokeproof towers—whatever term you choose. Neither of these codes even mentions smokeproof enclosures. The National Fire Protection Assn (NFPA) Standard 101, Life Safety Code, describes the facility in detail, but, oddly enough, it does not require any occupancy to install one.

The Building Officials and Code Administrators International (BOCA), formerly the Building Officials Conference of America, and the International Conference of Building Officials' Uniform Building Code, 1970 editions, both require smokeproof enclosures. In my opinion, the requirement is established on a proper and reasonable basis. Smokeproof enclosures are regarded not primarily as preferred exits, but rather as a fire-fighting tool—a really usable means of access for fire-fighting personnel to the upper stories of high-rise buildings. I believe there has been sufficient publicity and concern expressed in recent months to show that the needs of the fire services for built-in fire-fighting facilities have been seriously overlooked. Smokeproof enclosures are just one of many features which should be provided.

Smokeproof enclosures, when specified, are required in buildings 75 ft or more in height. Both the Basic and the Uniform Building Codes recognize that it is possible to meet the requirement by more than one method. But, in other cases, individual cities and counties have dealt with smokeproof enclosure requirements in a number of ways. Typical of how codes vary in their requirements (Fig. 2):

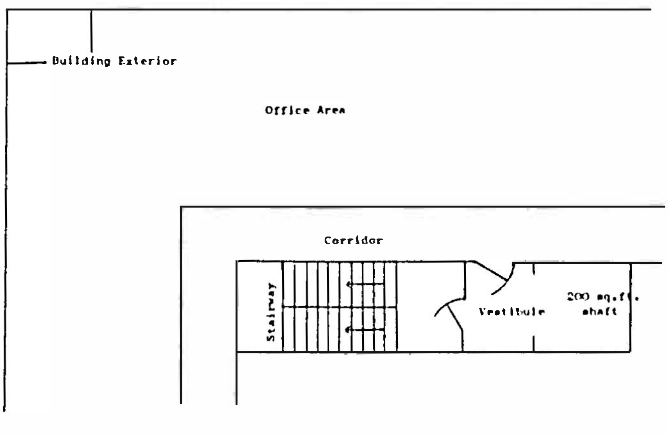

Fig. 2 Alternate Method of Providing A Smokeproof Enclosure

1. The vestibule is permitted to open upon a 50 sq ft court or smoke shaft.

2. The vestibule is permitted to open upon a shaft having an area of 100 sq ft, with no minimum dimension specified.

3. The vestibule is permitted to open on a court having an area of 105 sq ft, with a minimum dimension of 7 ft.

4. The vestibule is permitted to open on a court or shaft with a 200 or 300 sq ft minimum area, with a minimum dimension of 10 ft.

None of these alternates has really been tested, and would not, in my opinion, accomplish the job. I think they would all worsen the situation where safe exiting is concerned and would not provide a smoke-free stairway.

An explanation of the reasons which I see behind the requirement for smokeproof enclosures may be of some help. Fire department ladders can be counted on to reach only the lower floors of a building. Under ideal conditions, a 100-ft aerial ladder could possibly reach the seventh floor. A snorkel can do no better. But, ideal conditions seldom occur in building fires. Usually, the building is set back from the street; or the sidewalk is quite wide; or cars and trucks may be parked at the curb. So, the fire equipment will probably have to be well out from the building. In most cases, when the aerial-ladder truck or snorkel is placed in position, the ladder will not reach beyond the fifth floor. Up to the height which the ladder can reach, firemen will be able to get to the interior of the building in comparatively clear air. But, if the fire originates on an upper floor and a door is kept open for a while, smoke will enter the stair shaft. Or suppose that while trying to leave the fire area, and before smoke and heat make use of the corridor on the fire floor impossible, the stairway door is frequently opened and closed. In either case smoke entering the conventional enclosed stairway will rapidly render it impossible for use by anyone without special breathing equipment. An enclosed stairway normally is not vented. A small amount of smoke trapped in a stairway will soon make it untenable and unusable.

A simple vent at the top of the stairwell is not the answer because, as was shown in the extensive full-scale building fire tests, reported in the NFPA publication "Operation School Burning," smoke will not ascend the shaft until it is adequately warmed. Firemen entering the stairwell will have to contend with smoke all the way from the ground floor up to the fire floor. At present, fire departments do not have sufficient breathing apparatus available to supply each fireman with personal equipment. Even if such gear was provided, the capacity of the air or oxygen tanks would probably not be of sufficient capacity to last beyond the time needed to reach the fire floor. The air or oxygen would be nearly exhausted before the actual fire-fighting could get underway. If firemen in good physical condition are to reach the upper stories of high-rise buildings in good enough shape to carry on efficient fire-fighting and rescue operations, they must be able to reach the fire floor through a comparatively smoke-free atmosphere. That—and not to serve as a super-exit—is the real purpose of the smokeproof enclosure. Obviously, other steps are being taken or are under consideration to take care of the exceptionally high buildings. During the famous New York blackout of a few years ago, it was necessary for firemen to climb 40 and more stories to reach a reported fire—and that's not good even for a man in perfect condition. But, across the nation such buildings are not most prevalent; the "average" are 10- to 25-stories.

Certainly, a smokeproof enclosure would be a superior exit for those occupants who were fortunate enough to reach that particular stairway. But, the chances that a person will reach that particular stairway cannot possibly be better than 50–50, and may well be but one in three, one in four, or even worse. It is also quite likely that the smokeproof stairway will have heavy "up" traffic since it is the one specifically provided for the use of fire department and "down" traffic might be heavily impeded.

It is my opinion that the smokeproof enclosure must be regarded as simply another fire-fighting tool in the same category as the dry standpipe, the combination standpipe, the annunciator panel which designates the location of a fire, emergency elevator operation, etc., also required for taller buildings. If we were to regard the smokeproof enclosure primarily as a preferred exit for occupants of the building, then the codes should require that *all* stairways be of the smokeproof type.

It is my contention that the conventional smokeproof enclosure, as described in NFPA 101, is not infallable. Adverse weather conditions, wind, etc., may inhibit the escape of smoke through the vestibule open to the outdoor air. Actually, the smokeproof enclosure described has never really been tested.

In recent years, there has been an increasing demand on the part of architects and building owners for the "core-type" building—one in which the central area or core encompasses the elevators, stairways, service rooms, utility shafts, etc. With such a design, less space is needed for corridors which would be otherwise required to provide access to stairways necessarily located on the perimeter of the building or around a sizable "wasted area" shaft or court. Core-type design provides more perimeter offices and an overall increase in the amount of space available for rental. Some architects estimate that as much as 10% more space will be made available (but that doesn't really seem possible). The arguments in favor of eliminating smokeproof enclosures sound convincing. But, proper access to upper stories of the building for purposes of rescue and fire suppression is vital and is urgently needed.

As a result of the pressures applied for the elimination of the smokeproof enclosures, accessible only by way of vestibules open to the outdoor air, various substitute methods have been proposed and accepted—most without benefit of test. In one jurisdiction, the installation of an air duct was required adjacent to the vestibule leading to the stairway. No mechanical air movement was provided, only natural ventilation. In another, an air shaft approximately 16 sq ft in area was provided along one side of the vestibule. The shaft extended from grade to roof and was separated from the walking area of the vestibule only by a screen serving both as a pedestrian guard and as a means of allowing smoke to escape, hopefully without allowing smoke to enter the stair shaft. Not only did neither of these methods work as proposed but instead worked in reverse, forcing smoke into the stairway. One county accepted another substitute method calling for mechanical ventilation of the vestibule, but no forced ventilation of the stair shaft itself. Smoke entering that stairway has no means of escape. The stairway has a musty smell and it is difficult to rid the shaft of odors.

This matter was brought to a head in San Diego when the Board of Appeals required the Building and Fire Depts to establish an alternate method of providing the smokeproof enclosure. This is a switch because it is usual for the one seeking a variance to prove that his alternate is equivalent to that which the code specifies.

The San Diego Fire Dept obtained the use of a four-story hotel building soon to be demolished. A portion of the building was isolated for test purposes. Assistance in conducting the tests was obtained from the Los Angeles Fire Dept. Access to the stairway was from one direction only, simulating the end of a corridor. A door was provided to shut off the corridor from the vestibule and another door was placed between the vestibule and the stair shaft (Fig. 3). The vestibule was 46 in. wide and 54 in. long. The doors into and out of the vestibule were 3 ft by 6 ft 8 in. in size. Test fires were burned in a room opening onto the corridor which led to the vestibule. Test fires were made up of 35 lbs of wood, 9 lbs of asphalt-based linoleum, and a small amount of flammable liquid to get the fires going quickly. Fires were burned in a discarded bathtub, thereby restricting the amount of air so that dense smoke developed. Artificial smoke, such as is used in visibility tests, testing of refrigerated railroad cars, etc., was not considered suitable because, without accompanying heat, such smoke may not react characteristically.

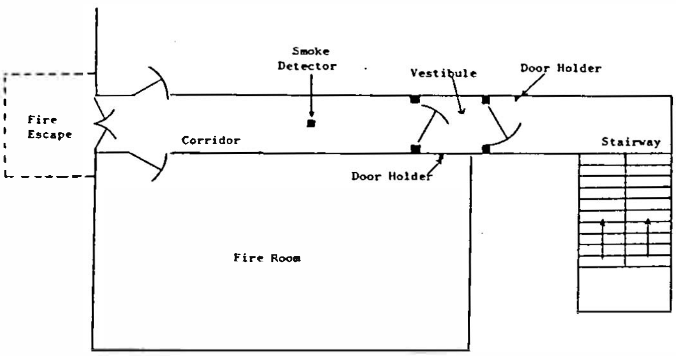

Fig. 3 San Diego Test

Smoke detectors set to operate at a 4% reduction in a 1-ft long beam of white light were installed and connected to automatic door-releasing devices to hold the vestibule and stair shaft doors open when the tests so required.

Various levels of ventilation were provided for the vestibule. A vestibule exhaust outlet, 75 sq in. in size, was installed 10 in. above the floor. This vent was available as needed for various tests. In the stair shaft wall at the second floor level, an inlet air opening, approximately 220 sq in. in size, was placed 3 ft above the floor. A blower was provided for this opening to be used as needed. At the top of the stair and adjacent to the door to the roof was a double-hung window that could be opened or closed as needed.

A thermocouple was provided in the fire test room and placed above the tub so that heat measurements could be taken in order to determine whether the heat produced would effect the smoke emission. Smoke density measuring equipment composed of a photo-electric cell and an electric light source was installed in the hallway outside the vestibule, in the vestibule itself, and at the top of the stair shaft in the penthouse area. Manometers were installed in the vestibule and in the stair shaft. Blowers were used to move the air as desired. The stair shaft blower, rated at 5000 cfm, could be adjusted by varying the size of the opening through which the air entered the stair shaft.

Various arrangements of air movements—gravity, forced, negative pressure, positive pressure, etc., were tried. Most were unsuccessful, but not all. It was found that when a negative pressure was established within the vestibule and a positive pressure within the stair shaft, the stairway could be kept acceptably clear of smoke.

As the result of these experiments, the Uniform Building Code was amended to permit the installation of either of two types of smokeproof enclosures, the naturally vented vestibule or open air balcony access to the stairway and the mechanically operated enclosure. The smokeproof enclosure attained by mechanical ventilation is required to meet the following requirements (Fig 4):

1. The opening between the corridor and the vestibule is to be protected by an approved 1 1/2-hr fire assembly. The door is to be automatic closing upon the detection of products of combustion other than heat. The door between the vestibule and the stairway is to be a tight-fitting door equal to not less than an exterior type solid wood door without voids, assembled with exterior type glue, 1 3/4 in. minimum thickness, mounted in a steel frame. Wired glass set in steel frames shall not exceed 100 sq in. in area. The door to the stairway is to be provided with a drop sill and other arrangements made, such as weather stripping, to minimize air leakage.

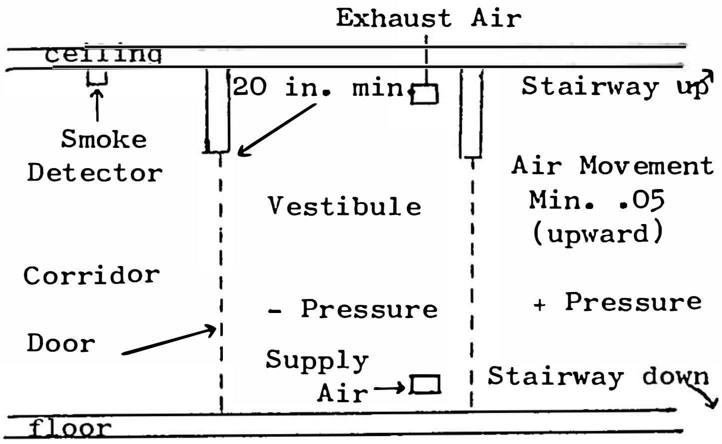

Fig 4 Smokeproof Enclosure Attained by Mechanical Ventilation

2. The vestibule must be a minimum of 44 by 72 in. in size.

3. The vestibule must be provided with not less than 1 air change per min and the exhaust must be a minimum of 150% of the supply. Vestibule supply air must enter and exhaust air must leave the vestibule through separate tighly constructed ducts used only for that purpose. Supply air must enter the vestibule within 6 in. of the floor level. The top of the exhaust register must be located at the top of a smoke trap, but no more than 6 in. down from top of that trap and be entirely within smoke trap area.

4. There is a requirement that the vestibule ceiling shall be at least 20 in. higher than the top of the door opening into the vestibule. This serves as the smoke and heat trap previously mentioned. For some reason, this was essential to the satisfactory movement of air in the vestibule and apparently results in the development of an upward moving air column within the vestibule.

5. Doors, when in the open position, must not obstruct duct openings. Duct openings may be provided with controlling dampers, if needed, to meet the design requirements, but they are not otherwise required. (At this point, a special note is added to the text of the Code. This was done to satisfy a specific requirement deemed necessary by the Los Angeles Fire Dept to meet a specific unexplained need. The Los Angeles Fire Dept conducted some additional tests of its own. To the best of my knowledge, it obtained no results different from those attained in the San Diego tests. But, Los Angeles City requires that the "stair shaft exhaust ventilation shall be by mechanical means and not less than 2500 cfm out of the top opening with any three adjacent vestibules in operation and with their doors open. Average local wind conditions shall be considered. The vestibule mechanical exhaust shall be a minimum of 2500 cfm measured with the door to the stair shaft open. With the vestibule doors closed, a pressure differential shall be maintained of not less than .100 in. water column below the minimum stair shaft pressure measured at that floor. Mechanical devices shall be installed to control airflow in each vestibule. The total capacity of the vestibule exhaust system is to be adequate to operate three vestibules simultaneously, measured with their doors to the building interior, open." In other words, a minimum 7500 cfm exhaust must be provided. If only one vestibule is in operation, that would mean an air change of approximately 30 per min. When two vestibules go into operation, there would be 15 changes per min, and if all three vestibules were in operation, there would be 10 air changes per min. Electronically operated dampers would be required in each vestibule, so arranged that they would be closed at all times until a detector signalled the opening of the damper on the fire floor. I think the Los Angeles City system is unnecessarily complicated, overly sophisticated, and of questionable dependability with the passing of the years. But, the Uniform Building Code does not prohibit such an installation if the designer wants to install it.)

6. The stair shaft must be provided with mechanical supply and exhaust air. There must be a minimum of 2500 cfm discharge at the top of the stair shaft. The supply must be sufficient to provide a minimum of .05 in. water column pressure with respect to atmospheric pressure with all doors closed and a minimum of .10 in. water column difference between the stair shaft and the vestibule. (I would like to make it very clear that building codes are necessarily minimum. If the design should provide a pressure differential of more than .10 between the vestibule and the stair shaft, that is all to the good. If you are worried that a great pressure differential will inhibit the opening of a door, we tried a situation with .39 in. of water column difference between the stairway with a pressure at the knob location varying from 16 to 32 lbs.)

7. Exit doors into both the vestibule and the stair shaft may be held open with approved door holders of the fail-safe type, which will permit the door to close automatically when released by a detector of products of combustion other than heat. The detector is to be located in the corridor on the ceiling opposite the door to the vestibule. The operation of that detector shall also set the vestibule and stair shaft mechanical equipment into operation. Some officials want the blowers to operate continuously at a reduced level and then go to full capacity when the detectors are activated.

8. The mechanical ventilation equipment shall be provided with an approved self-contained generator which will go into operation automatically whenever there is a loss of power in the normal house current. The generator must be in a separate room of fire-resistive construction and have a minimum fuel supply adequate to operate the equipment for 2 hrs.

It is extremely important that a test be conducted of the system before it is accepted. The use of mechanical or artificial smoke is satisfactory for this test.

The present requirements specify that in buildings with air-conditioning systems or pressure air supply, a products-of-combustion detector shall be placed in the return air duct prior to exhausting from the building or being diluted by outdoor air. It shall be so located as to operate and shut off the building system in the fire area in case of smoke in the air stream. Recently, there have been some second thoughts on this matter of shutting down the supply air and I think it might be more appropriate to maintain the air, continue the exhaust operation and bypass the return air so as to remove it from the building. This is still subject to debate and it is not consistent with what the code now specifies nor with requirements of NFPA 90A.

The Basic Building Code was modified in 1970 to come into quite close agreement with the requirements of the Uniform Building Code. The Basic Building Code does require greater fire-resistive construction of the shaft walls. It will still permit the natural ventilation system, but with the vestibule opening into a 10-ft minimum dimension 200 sq ft area. The mechanically operated vestibule would require 2 air changes per min instead of the 1 per min called for in the Uniform Building Code.

Both the Uniform and Basic Building Codes require that the stairway emergency lighting be connected to the emergency generator. While the Uniform Building Code does not specifically require an annunciator panel at the main entrance to the building, as does the Basic Building Code, each building, with which I am acquainted, using the mechanical system does have that panel. The Basic Code requires the building engineer to keep a log of tests conducted at least once every 30 days. The Uniform Building Code people thought this was beyond the scope of a Code requirement.

I am convinced that the mechanically operated system is feasible, dependabie and even preferable to the natural ventilation type smokeproof enclosure. I believe that it would be fairly effective if only because of the dilution provided by the stair shaft ventilation. I am opposed to the so-called Los Angeles City system because it is too complicated and requires unlisted electronically operated dampers in each vestibule. I have serious doubts about the proper operation of that system after 10 or 20 years.

During the testing of some of these installations, I have encountered problems, i.e. motors not running to speed, the specified air delivery no being delivered, blowers running in reverse, etc. But, in so doing I did learn that even when the vestibule systems did not operate as required, but with the stair shaft having the required air movement, there actually was a pretty good condition. Possibly, the amount of air supplied and exhausted was sufficiently to dilute the smoke to such a degree that the stairway was usable. This dilution would not be present in the conventional natural ventilation type smokeproof enclosure nor would it be present in the typical enclosed stairway. As a result, some building officials and fire marshals who have witnessed the tests are now requesting that stair shaft ventilation be provided even in the ordinary enclosed stairway—the one without a vestibule.

According to a recent article, the Russians have been doing some testing using scale models of buildings. There has been no correlation made with an actual building. The drawings accompanying the article showed that air was being supplied from the top of the model, but they don't show where it goes. In essence, the article indicates that air dilution may be satisfactory to accomplish a reduction in the temperature build-up to an acceptable level.

The Canadians have done extensive research along this line and have apparently arrived at other solutions which will accomplish the same end results.

But, there is still work to, be done.

PAMPHLET 90A CONTROLS SECTION

A. P. ROBINSON
Associate Member ASHRAE

Pamphlet 90A is a publication of the National Fire Protection Association (NFPA). The most current edition was published in July, 1971. To some, 90A is a design guide, and to others, its recommendations are law. Since the pamphlet has been revised 19 times since 1937, it is always important to make certain that the edition you are using is current and that the current edition is locally adopted.

Pamphlet 90A assists in identifying the additional fire safety practices needed for an air-conditioned building as opposed to a non-air-conditioned building. The topics discussed in the pamphlet are as follows: Construction of Ducts; air intakes and outlets; air filters; fans; electric wiring and equipment; air cooling and heating equipment; automatic fire doors and dampers; controls; maintenance; and smoke removal.

Specifically this paper will discuss the controls and the smoke removal sections. This discussion will follow the 90A theme of providing a minimum requirement for safety to life and property from fire, discuss what 90A recommends, and perhaps clear-up some misinterpretations of the recommendations. Pamphlet 90A discusses fan systems of certain cfm of air deliverance capability. In all cases, it is valid to say that a fan system's delivery cfm is made up of the total cfm's of each fan attached to the supply side of the system. In other words, an air conditioning unit with three 5000 cfm supply air fans is classified as an air-conditioning system of 15,000 cfm.

Pamphlet 90A requires that each air-conditioning system have a conveniently located manual emergency stop switch in order to shutdown the fan in case of fire. The local authority having jurisdiction provides ultimate approval for the switch location.

In a small fan system, (see Fig. 1), the equipment room is generally located adjacent to the area served by the unit. If there is no lock for the equipment room door, then perhaps the air-conditioning unit fan motor starter disconnect switch would serve well as a manual emergency stop switch. A person would need only go to the equipment and shut off the fan if either a fire or a smoke condition were observed. This simple solution depends upon: (1) An unlocked equipment room which doesn't often occur. More often than not, small equipment rooms are used for maintenance storage of mops, etc. and are consequently locked. (2) Occupants knowing the location of the air conditioning unit fan motor starter switch, how to use it, and importance of using it.

This solution is offered because it is the most commonly used solution, and it is economical. On the other hand, it is obvious that a person observing a quantity of smoke pouring out of a supply diffuser will have little to motivate him to go into an equipment room and shut off a fan. A person's primary motivation in such a circumstance would be escape. If the emergency switch is located along an exit route, then perhaps an excited occupant would activate it as he went past.

In looking at the more complex air-conditioning system with more than one area being served by the air-conditioning unit, it becomes most apparent that the fan motor starter disconnect switch is going to be unsatisfactory as a manual emergency fan stop switch (see Fig. 2). Some reasons are:

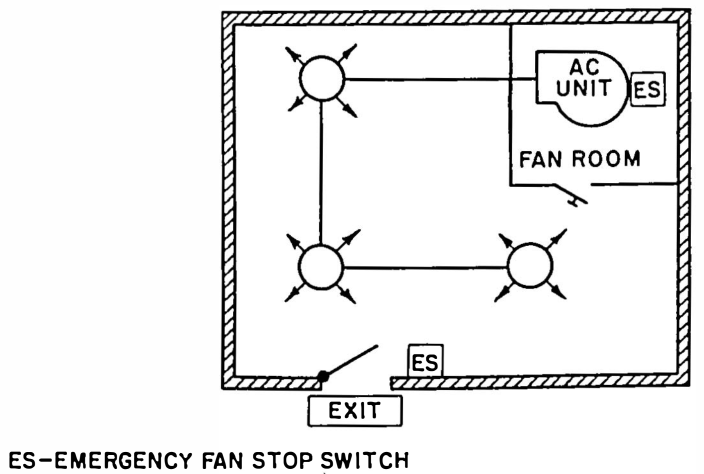

Fig. 1 Small Fan System showing two possible locations of the required emergency fan stop switch

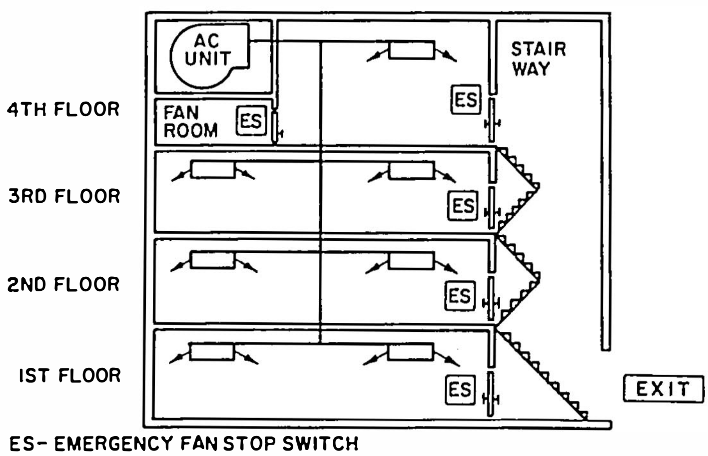

Fig. 2 Large Fan System showing floor emergency stop switches located at entrance to exit way and at air-conditioning unit

(1) Many people don't know where their particular floor lighting panel is located, much less the location of the motor control center which houses the air-conditioning unit fan motor starter.
(2) Most equipment rooms are kept locked in large buildings.
(3) The motor starting equipment is remote from the area served by the air-conditioning equipment and is not generally on the way to an exit.

The conclusion is: If it is important for building occupants to be able to shut down their air-conditioning-systems upon sensing fire or smoke, then it is necessary for the disconnect switch to be located in the area served by the air-conditioning unit. It is felt that they are a good device to use as a first stage in the protection of area occupants and property from fire and smoke damage and associated panic and loss of life. Hopefully, Pamphlet 90A will elaborate its recommendations with regard to these switches. Since 90A allows local authorities having jurisdiction to determine switch location, there is considerable non-uniformity.

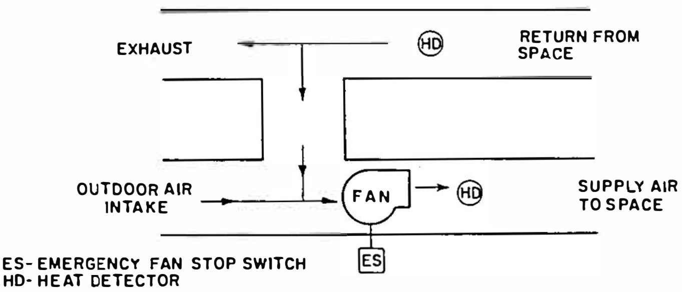

Fig. 3 Small Air-Handling Unit 2000 to 15,000 cfm with required heat detectors

Air-conditioning systems whose total fan delivery cfm is between 2000 cfm and 15,000 cfm are required by Pamphlet 90A to be provided with Underwriters Laboratories (UL) approved thermostatic devices (see Fig. 3). One device is to be located in the air-conditioning unit return air stream prior to either exhausting or outdoor air dilution. This device is to be set for 125 F. If the air-conditioning unit does not utilize return air, then the exhaust device, if provided, should have a thermostat located in its suction. Another device is to be located in the air-conditioning unit supply air stream, down stream from the last filter section. This device is to be set for 50 F above the highest expected discharge air temperature. Either device, upon sensing set point temperature, is to be arranged to stop the unit fan. The devices are to be of the manual reset type or connected to a fire alarm system requiring manual reset. Pamphlet 90A allows the substitution of smoke detectors approved for duct installation in lieu of using thermostatic devices (see Fig. 4). Unless the end user of the area served by the air-conditioning unit or the local authority having jurisdiction recognizes a pronounced need for early warning, it would not be expected that smoke detectors would be substituted for thermostatic devices on these 2000 to 15,000 units. An installed duct mounted smoke detector with fan shut-down contacts costs many times more than an installed manual reset type fire thermostat. If it is important to life or property safety for certain 2000 to 15,000 cfm units to utilize smoke detectors, then the

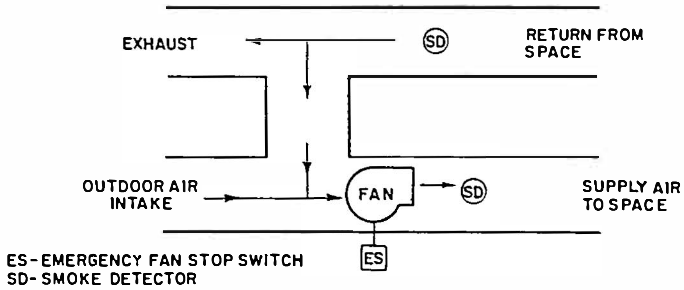

Fig. 4 Small Air-Handling Unit 2000 to 15,000 cfm with substitute smoke detectors

NFPA may have to specifically identify those applications. The task of identification has been begun in Pamphlet 90A which recommends smoke detection in systems of 15,000 and under where the panic hazard is pronounced or where there are valuable contents which are particularly subject to smoke damage. Smoke detectors are listed in the UL's Fire Protection Equipment List. Two categories of smoke detectors are listed: (1) combustion products type and (2) photo-electric type. Current trends in the detection industry are moving away from the photo-electric type and seem to be permanently leaning towards the use of the combustion products type. Either type properly installed and maintained does a satisfactory job of detection. There are numerous manufacturers of both types of detectors listed in the UL's Fire Protection Equipment List.

Pamphlet 90A requires the use of smoke detectors arranged for fan shut-down in air-conditioning systems whose total fan cfm is 15,000 or more (see Fig. 5). The recommended location of the detectors in these larger fan systems is the same as the location of the thermostatic devices in the smaller 2000 to 15,000 cfm systems. These larger systems present problems in the application of smoke detectors. The detectors are placed directly in the units or use sampling tube assemblies which allow the detector to be mounted outside the unit. In some instances, the detectors are placed in both locations. The combustion products type, not unlike the photo-electric type, depends upon the products of combustion or smoke being brought into the detector area of influence before an alarm or action can be initiated. Multiple detectors are essential where stratification is suspected. Where pure mixture is proven, then multiple detectors do not appear to speed detection. The most commonly used answer to the dilution problem is the location of detectors in the hazard area.

The detector in the supply air detects smoke or products of combustion coming from a fire within the unit, or

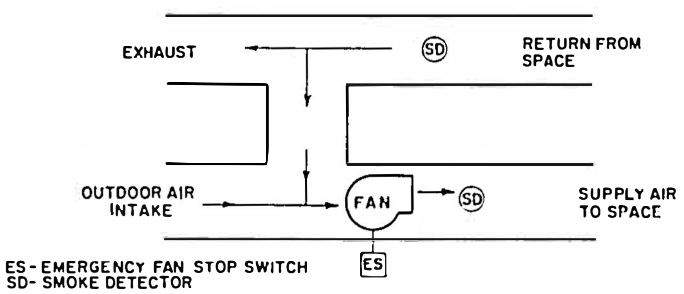

Fig. 5 Large Air-Handling Unit over 15,000 cfm with required smoke detector

smoke or products of combustion being brought in from the outside. I know of an unprotected high rise building in the Middle Atlantic states which was pumped half full of undetected smoke from a fire outside the building.

Pamphlet 90A recommends the use of smoke dampers on units over 15,000 cfm (see Fig. 6). These dampers are to be located in the supply duct work system and in the return duct work system where they would do the most good in sealing the unit against the natural flow of smoke after the air fans are shut down. There has been a lot of publicity given to the fact that the UL does not have a smoke damper listing. It may take a long time for criteria to be developed to have such a listing. During the interim period, the use of required automatic control type dampers in the return duct work and in the supply duct work arranged to shut when the fan stops will suffice to do the job. The return air damper is a usually required damper so only the supply damper is additional. Additional controls are required on the normally open return air damper to close it when the unit fan is shut down due to smoke detection which activates emergency fan disconnect switch.

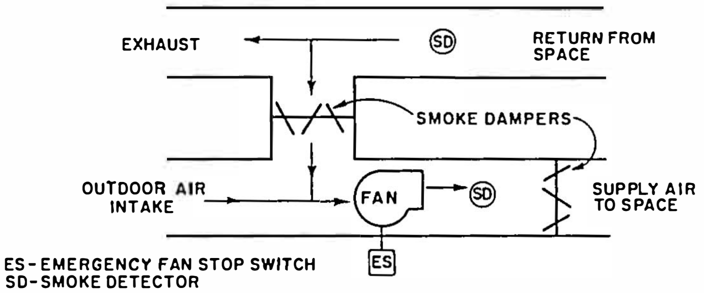

Fig. 6 Large Air-Handling Unit over 15,000 cfm with required smoke dampers and smoke detectors

Units which serve more than one floor of a multi-floor building present smoke detection design problems. The detector in the supply duct makes sense due to unit fires and smoke from outside sources. The detector in the return air is given a tremendous monitoring job. As the units grow in size and return cfm, then it becomes more apparent that due to dilution by clean air from non-fire areas, a major fire in a multi-story building might grow undetected by an air-conditioning unit return air smoke detector. To be sure, the detector would operate before the entire return air duct work system were full of smoke which was the 90A reason for having it there. Too often people expect area protection from detection systems installed to prevent the recirculation of smoke or products of combustion. Pamphlet 90A was not written as a guide for the installation of area detection systems. Perhaps someday, the NFPA will outline guides for area protection.

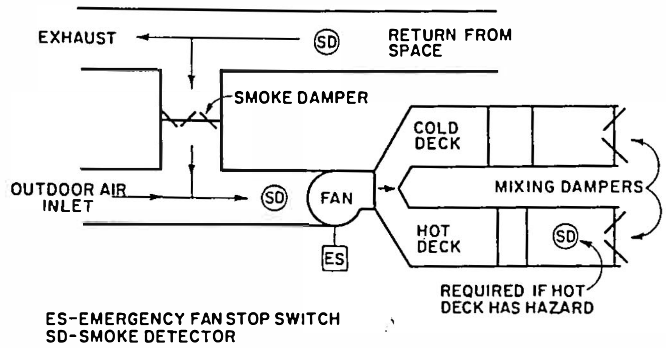

Fig. 7 Multi-Zone Unit over 15,000 cfm with required smoke detectors and smoke dampers

Multi-zone units in the over 15,000 cfm category present problems in the application of supply air smoke detection (see Fig. 7). It is not economically feasible to install a detector in each zone, consequently, a detector is normally installed in the fan suction or immediate discharge. If the hot deck has heating apparatus, which is hazard suspect then the deck itself should also be protected. Care must be exercised in using ionization type detectors in such decks if products of combustion are normally in the deck due to the heating apparatus. Due to cost and construction difficulties, smoke dampers in the supply are not usually installed in multi-zone units or large built-up high velocity double duct units.

Instead of fan shut-down, the pamphlet allows the use of the air-conditioning apparatus to purge the building of smoke. The pamphlet does not recommend such purge systems, it only allows them. It does not outline the methods to be used in the arrangement of the air-conditioning apparatus, it merely cautions the user against compromising the air-conditioning systems integrity by subjecting it to temperatures and conditions for which it was not designed. Pamphlet 90A allows the use of purge systems if you can design one which meets your needs.

SMOKE CONTROL IN HIGH RISE BUILDINGS

J. BROOKS SEMPLE
Member ASHRAE

FIRE . . . the destroyer of property; but as a threat to human life smoke is much more significant. Smoke is the killer of 85% of the so-called fire victims. When the fire gets to the smoke stage in a room within a building, the oxygen is depleted and the real threat to human lives begins. For example, visualize a typical smoldering fire: the flame is not spreading. It is under control in that there is no more oxygen; there is no more propagation of flames but the very lack of oxygen is what causes death. This condition, this smoke, this obscuration not only contributes a tremendous amount of panic but also has hidden in it many deadly toxic gases and the greatest asphyxiant of all, carbon monoxide (Fig. 1).

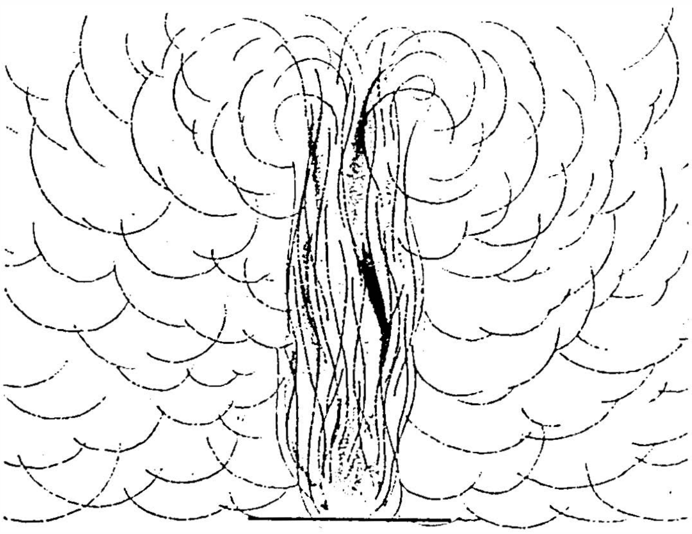

Fig. 1

Depicted in Fig. 2 is the analysis of acrylic fibers under pyrolysis in its full meaning: not only combustion but also thermal degradation. Beginning with full oxygen supply and full combustion of acrylic fibers, a small, almost insignificant, amount of nitrogen oxides are given off. However, as the room begins to fill with smoke, and more importantly as the oxygen becomes depleted, the quantities of nitrogen oxides are increased approximately threefold and hydrocyanic acid is also released (Fig. 3). This second agent is so deadly it is used for public execution in the State of California.

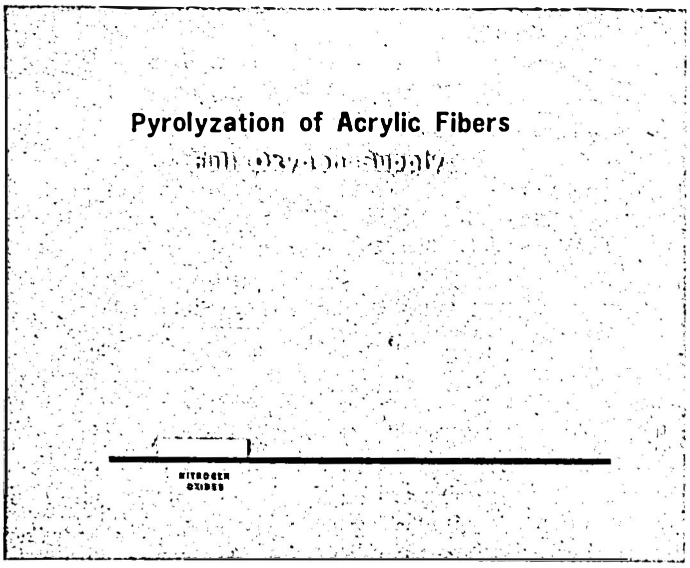

Fig. 2

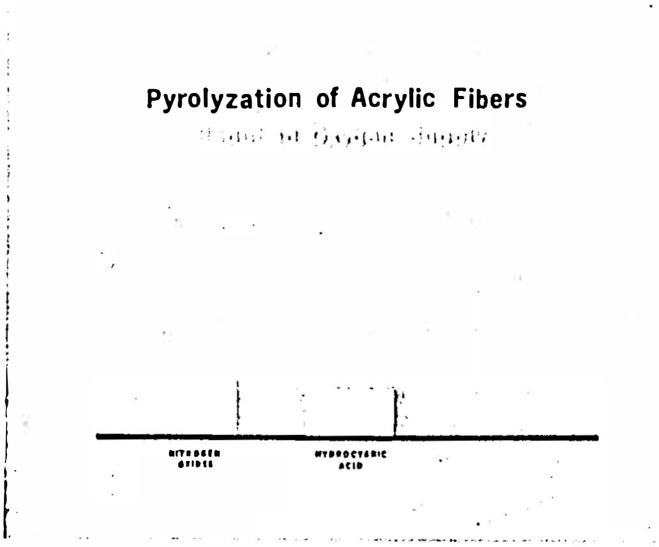

Fig. 3

Finally, when all of the oxygen is depleted and thermal degradation is complete (Fig. 4) not only are the first two elements greatly increased, quantitatively, but also a third toxic element, menthane, is emitted. In addition to its

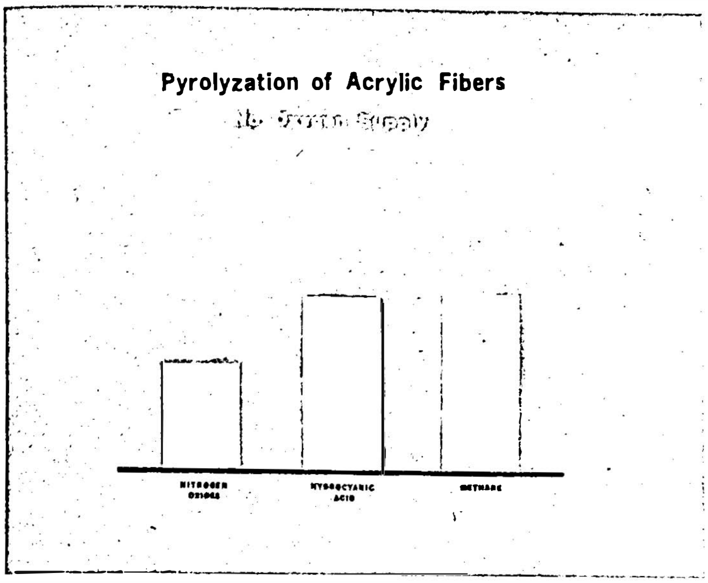

Fig. 4

toxicity, menthane is well known as an extremely volatile fuel. It is this package of deadly gases expanding under fire pressure which gradually forces its way out of the fire zone through the duct system, very frequently past fire dampers which are insensitive to the passage of these gases, into spaces still containing oxygen. Then all it takes is a small spark and the building blows up. It is not necessary to have explosives in the building to have it explode.

It is because of these toxic and explosive gases and carbon monoxide, given off from the infinite number of building materials and contents in a fire, that I wish to stress to the engineering fraternity the havoc smoke really causes. The fire fighting profession has been aware of this for years. It is high time the public learns it as well.

Concerning hardware, smoke dampers are entering more and more into building plans. The National Fire Protection Assn's (NFPA) Standard 90A on Air Conditioning & Ventilating Systems stresses control of smoke in the fan room only. These dampers are required in systems in excess of 15,000 cfm and they must shut off complete flow on both sides of the air circulating fan. These dampers

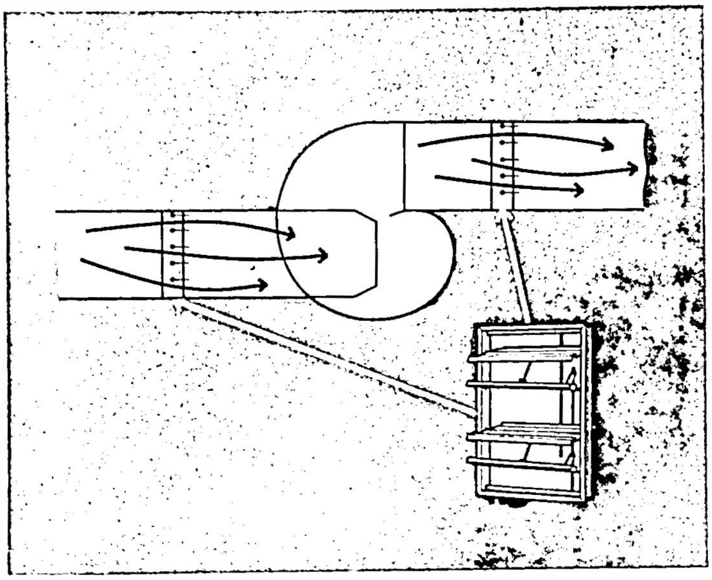

Fig. 5

must be arranged so as to close whenever the fan is shut down; therefore, a motorized air control damper is ideal (Fig. 5). Additionally, one or more dampers are already in position as part of the air handling and mixing system; it is not necessary to add additional dampers in this case, but only to rearrange the controls so that the already existing air control dampers may be utilized as smoke control dampers in the fan room. Obviously these dampers cannot close whenever the fan is operating. The are closed only against the gravity flow of smoke. Should a fire occur when the fans are shut down, the dampers are already closed. Should smoke in the duct system trigger the detectors the fan will also shut down and thereby cause the dampers to close.

It is important to note that there is nothing contained in Standard 90A that has anything to do with smoke dampers outside of the fan room. Fig. 6 shows a typical smoke-stop barrier as required by NFPA Standard 101—The Life Safety Code. These barriers are required to be constructed as shown, not just to the ceiling but to the underside of the floor or roof above. This type of construction is identical to that required for 2-hr fire partitions even though Standard 101 only requires a minimum of 1-hr fire resistivity in smoke-stop barriers. There are many localities, in some instances entire states, which require fire dampers in all 1-hr fire partitions. All penetrations of smoke-stop barriers must be protected with fire dampers in such localities. The Hill-Burton Act, in supplying federal funds for local hospital construction, has dramatized and expanded upon Standard 101 requirements so that it is now general knowledge that all smoke-stop barriers require

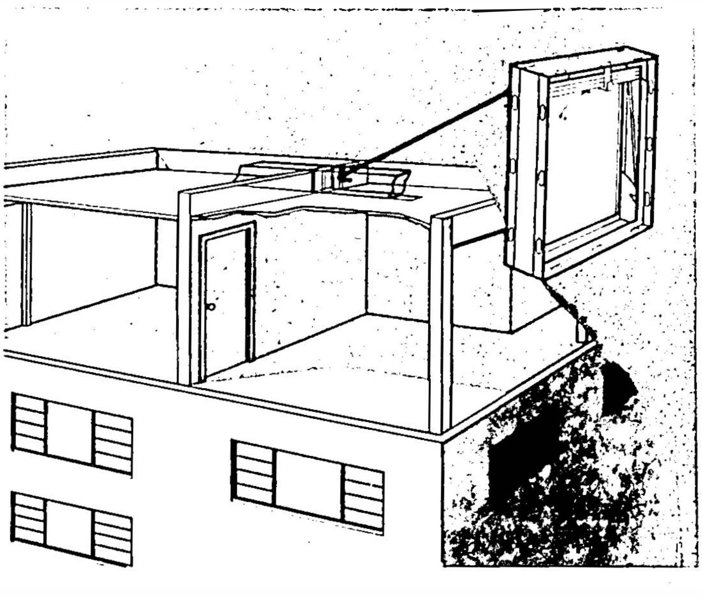

Fig. 6

smoke-stop dampers within the ducts which penetrate such barriers. Whether fire dampers are required or not in your jurisdiction within 1-hr fire partitions, it still makes a great deal of sense to use fire damper type construction when a 1-hr fire partition is being penetrated.

A smoke-stop barrier damper and a fire damper have a great deal in common. Their basic functions are identical. When fire occurs—to supply enough heat within a duct to melt the fusible link—the fire damper then closes, but it never closes for any reason other than the local hazard in the duct.

Ideally, a smoke-stop damper will not close unless there is smoke in the duct in the immediate vicinity of the damper; at that point it must close (Fig. 7). It is definitely not necessary, and as a matter of fact not desirable, for it to close for any reason other than a local hazard. This is certainly not the proper location for a motorized air control damper to open and shut obediently every time the main fans are turned on or off by manual or automatic operation. The smoke-stop barrier function has absolutely nothing to do with the cycling of the main fans. Any deviation from this separation of functions is erroneous engineering extrapolation. Not the least of good reasons to eliminate air control type dampers in this area is the fact that control dampers are commonly gasketed with material which will not only add to the fire but add greatly to the smoke. Neoprene and polyurethane are commonly used gasket materials. Both of these will definitely add toxic fumes to the air stream when heated to several hundred deg F. Certainly this is not what is desired in a smoke-stop barrier in a hospital, nursing home or any other occupancy for that matter.

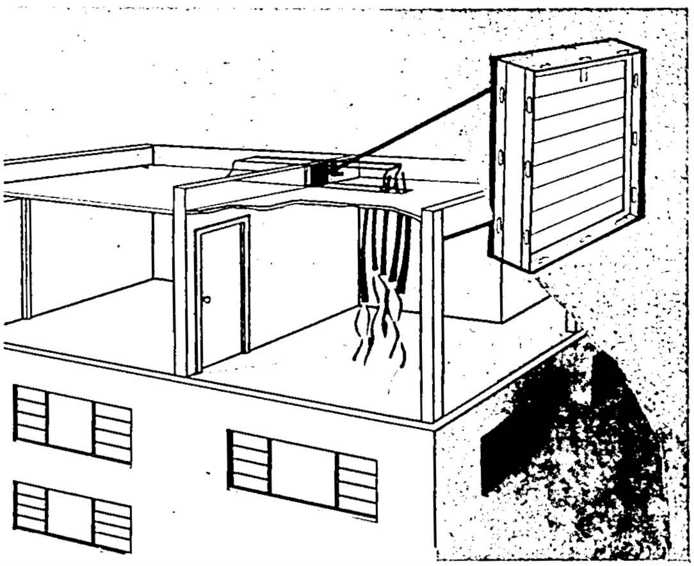

Fig. 7

It is desirable to have dampers as smoke-tight as possible and with this particular design (Fig. 8) it has been accomplished by the use of a stainless steel jam gasket. The jam gasket bears on the edges of the blades to provide a tight seal when the blades are in the extended or closed position. Because of this drag it is necessary to spring-load the blades even when the damper is in a vertical position. It also has the advantage that the damper can be used in a horizontal position, which cannot be accomplished with a stall motor or a solenoid-operated type smoke damper.

Highly reliable, low cost, electrically sensitive fusible links have recently been developed to convert both old and new fire damper designs into combination fire and smoke dampers. In short, industry has developed, and Underwriter's Laboratories Inc has tested and listed the necessary hardware to do the job. It is now up to concerned engineers to apply it.

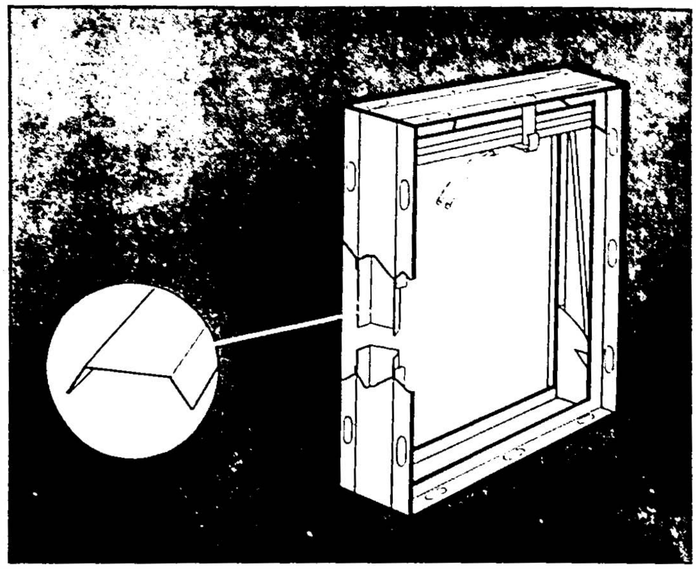

Fig. 8

A typical building under construction in the city of Philadelphia (Fig. 9), is 40 stories high and has one fan room for every 10 floors. The left hand shaft is exhaust duct, the middle shaft is return, and the right hand shaft is supply. The stair towers and elevator shafts are shown in a typical center core arrangement.

Let's start the fire shown in lower right, Fig. 9. At this point there is no effect on the automatic detection system which must be installed in this building under the requirements of Standard 90A. To get some reaction, it must burn longer. Smoke and poison gases are ventilated directly to the outside through the exhaust duct, which is commendable. Additionally, smoke, poisons, and obscuration are picked up in the return system and piped past the required smoke detectors in the air handling room. Still, there is absolutely no reaction. Why? Simply because the smoke is diluted 19 to 1 from the clean returns from the 19 other half floors served by this air handling system.

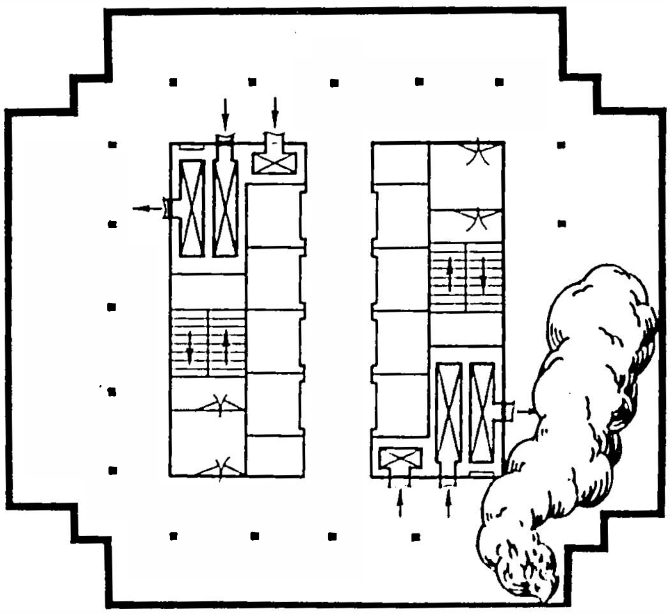

Fig. 9

Fig. 10

So, it must burn some more. Now, (Fig. 10) there is exhaust from two areas and smoke is picked up and piped directly into the fan room. The dilution is still 9 to 1 and no reaction. Detection equipment can be set to be sensitive to that degree of dilution but the building owner would have nothing but a string of false alarms with such a high degree of sensitivity in the air handling system. In actual installations, the detectors are set at a relatively low range of sensitivity so that the condition shown in Fig. 10 will have to be duplicated in at least one, if not two more, of the floors so that approximately one-third of the 10-floor segment will be completely permeated with dense smoke. From the smoke beginning to leak into the elevator shafts, it is apparent that, by the time this condition has built up on three floors, the elevator shafts would definitely be out of service.

Finally then, according to Standard 90A, the fans would shut down. Why? Obviously to prevent the smoke from being circulated to other areas not yet contaminated. That's great, but every person remaining in the contaminated areas is absolutely assured of no further supply of fresh air. There is another function required of this same system to be performed by this Standard—that is alarm. But the alarm Standards of NFPA require that once a building alarm is sounded the entire building must be alarmed which will result in immediate attempted total evacuation.

The Federal Fire Council has made a study of federal office buildings and other high-rise structures. It has been found that, on the average, it takes 1 min per floor for the last person to get within the relative safety of the stair tower. That means, in a 40-story building it would be 40 min before the statistically last person has his blue-faced body fall through the stair tower doors. That's not all. A member of the National Research Council of Canada has worked up a time of evacuation by stairs in high buildings. He notes that the net resultant discharge from stairs, in the number of people per min, increases as the density increases from 15 sq ft per person all the way down to 3 sq ft per person. The concentration of people more than makes up for the reduced velocity of flow up to and including 3 sq ft per person. It falls off significantly at 2 1/2 sq ft per person but it stalls dead at 2 sq ft per person. That is, *it doesn't move at all.* Nobody moves when they are allocated 2 sq ft or less. This condition prevails many times in the total evacuation of high-rise buildings. That, then, is precisely the limit of the life safety that is provided for you and your families in high-rise buildings by the current Standards.

Take an identical building and apply some of the knowledge and design criteria stipulated for hospitals and nursing homes. Subdivide each floor into two separate smoke zones (as in Fig. 11). With center-core construction it is relatively inexpensive because the center core partitions must be of 2-hr fire construction and are, therefore, already smoke-stop barriers as well. It is only necessary to add doors at both ends of the elevator lobby as well as connecting smoke barriers from the core to the outer wall at two places shown. This can be accomplished merely by persuading the architect to upgrade the construction standard of several of the partitions so that they go from slab to slab and are given a fire resistive rating of not less than 1 hr.

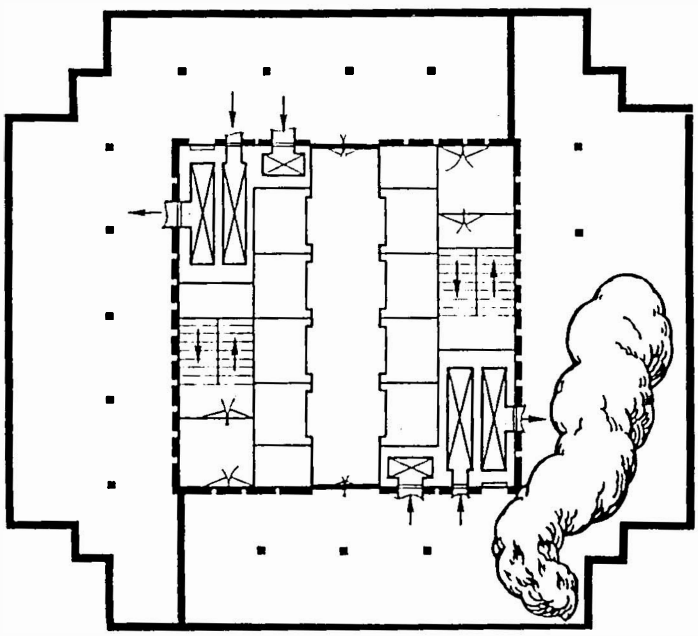

Fig. 11

Given the same fire, at this stage nothing will happen (Fig. 11). But, exhaust has been vented to the outside and a very minor amount of smoke has entered the return air system. Finally (Fig. 12), smoke is drawn within the chase itself.

Fig. 13 shows how this is done. The return duct is furnished with a duct type smoke detector (large black dot). The dotted line to its left shows the sampling tube so that all return air is constantly monitored. When the one-half floor constituting this particular smoke zone has smoke in one-third of it, there is sufficiently dense smoke to trigger the detector and to provide an improved method of personnel protection:

1. Alarm, but not throughout the entire building. Only

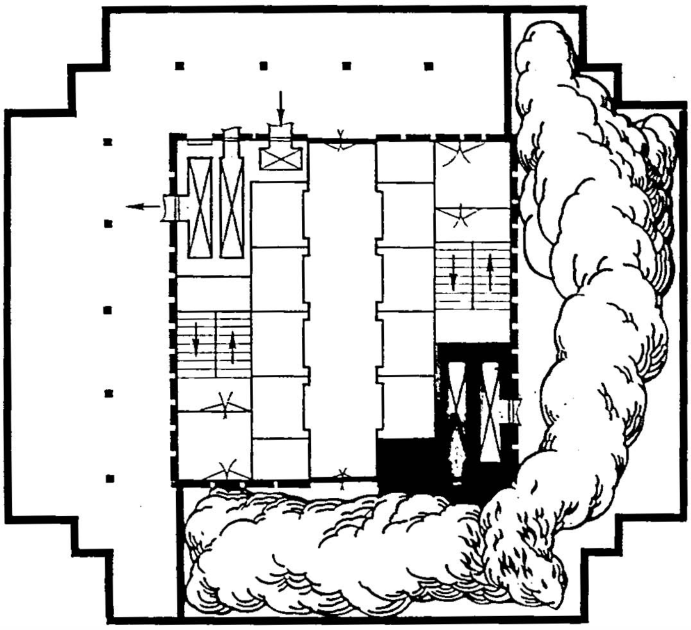

Fig. 12

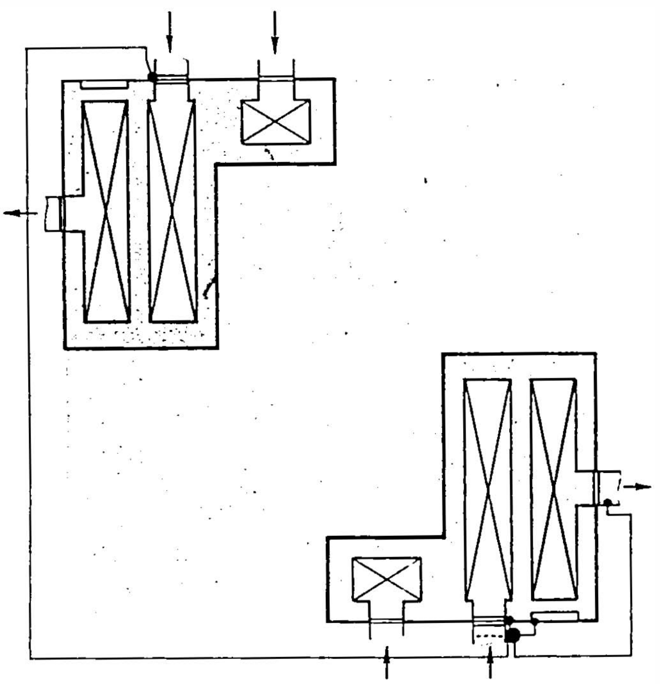

Fig. 13

the smoke floor and the floor immediately above are alarmed. Therefore, there is more than adequate stair tower for evacuation if needed. But the alarm doesn't stop there. Also required is a direct wire to the local fire company so that it is definitely called and on the way.

2. Fire dampers already in place are actuated at the return and supply branches off the main risers. These fire dampers must be provided under current codes. All that is necessary is to upgrade them to combination fire and smoke dampers by adding metallic gasketing and electrically operated actuators.

3. The special vent system, is opened up; that is, the small white damper in the lower right hand corner is electrically released to open. It is a normally-closed, tight-sealing, spring-loaded, air control damper which opens and simultaneously turns on an exhaust fan on the roof. This fan sets up a tremendous negative pressure in the open area around the ducts. If such a large free area cannot be provided within a single shaft, it might be better to design a separate and distinct smoke shaft. In any event the smoke exhaust fan is to be designed to evacuate a minimum of 15 changes per hr from the largest single connected smoke zone.

4. An electrical impulse is sent around to the other part of the same floor to close return damper in that area.

Looking at the system under normal operation, it is apparent that the supply is balanced by the return and exhaust, maintaining the same pressure inside the zone as out. In event of the detection of smoke, supply and return close, exhaust continues and the vent is opened introducing a substantial negative pressure within the smoke zone.

If there is a tremendous amount of fuel and the fire company is delayed getting to the site, it may be necessary to actuate the ordinary fire dampers (212 F standard links) in both the exhaust and the vent openings in order to protect other floors from the spread of fire within the shaft. The system is capable of sealing itself. However, in most cases with the quick response time now experienced by major city fire companies, they generally can get to the site and start suppressing the fire and heat before this condition would be reached.

Referring back to Fig. 12, it is now apparent that the clean area to the left is a safe area of refuge because it is under pressure and anyone evacuating from the smoke zone through the smoke doors (which will have to be installed in the smoke barriers) will be evacuating from a relatively low pressure to a higher pressure, enabling the smoke to be detained behind and providing them with a supply of fresh air as they are evacuating. Normally, the air-conditioning system in the area of refuge will be set up for approximately 6 to 8 air changes per hr providing only about 50% make-up air for the 15 times exhaust capacity required in the smoke zone. Two points to be made are:

1. Some may criticize making up air to a fire with this system but, do not forget, this entire system is built around life safety and not property protection. The building should burn. It should burn cleanly, and rapidly but, nevertheless, people can get out more easily with a clean fire than a smoldering, smoky type.

2. If make-up air is to be provided why not provide 100% by continuing to supply fresh air directly into the smoke zone? The answer lies in the elevator lobby. People, being human, are not subject to engineering, particularly in times of panic and stress. Most people would tend to go directly to the elevator lobby thinking simply "I came in this way and I want to get out this way." The problem is that elevator shafts are frequently under negative pressure. An elevator shaft and the adjacent lobby are going to have identical pressures because of the loose fitting doors. One cannot determine the pressure in the lobby unless all factors of weather, type of air conditioning or heating, height of building and the particular floor on which the fire occurs, are known. Only when all these factors are available can that pressure be determined. However, it can be safety stated that more than 50% of the

time it will be somewhat less than ambient pressure. Therefore, the elevator lobby must be designed for a negative pressure. Having that design condition, the pressure in the smoke zone must be still lower. For this reason, a system must be provided having a substantial negative pressure in the smoke zone. This takes care of not only the elevator lobby but also the stair towers which are subject to the same problems as elevators but not as severe.

These provisions as outlined may be criticized as revolutionary or expensive. I have only one defense. This plan will save lives. Our whole exit hardware design theory did not come from you. It did not come from the architects. It did not come from any professionals. It came from the Iroquois Theater in 1903 when 602 people died in panic. But that didn't stick. That engineering was too old and the whole business had to be redesigned in 1942 in Boston at the Cocoanut Grove when 492 people were killed by smoke inhalation and panic. Almost 1100 people, in two tragedies alone, dedicated, albeit unwillingly, their lives towards safer exit design. Just a few months ago, 144 French teenagers were trapped, tampled and asphyxiated under identical circumstances. Will we ever learn? On the subject of sprinklers 95 pupils and nuns died in the Our Lady of Angels school fire in Chicago. Our sprinkler codes are now slightly more up to date. When it comes to smoke, 32 elderly people perished at Marietta, Ohio in a nursing home. A building code variance was applied for and permission received to leave out the smoke-stop partitions and save $3300, at a savings of $100 a life. How much longer must we design by disaster?

CAN SPRINKLER SYSTEMS SOLVE BUILDING CODE PROBLEMS?

E. J. REILLY

Can sprinkler systems solve building code problems? What are the problems? Whose problems are they? Can sprinkler systems solve those problems?

WHAT ARE THE PROBLEMS?

To help answer this question, lets ask another question – a more fundamental one. Why do building codes exist at all?

A building code is a law. As a law, its only purpose is to provide for the public health or the public safety. So lets dispel the notion that building codes have anything to do with the preservation of private property – except insofar as the protection of private property as directly related to the public safety.

Let me illustrate.

Every building code, including the four nationally recognized Model Building Codes, contains a *Statement of Purpose* in its first chapter or in its preface. Let's take an example:

> The Uniform Building Code is quite typical of all building codes insofar as its *Statement of Purpose* is concerned.
>
> Part One, Chapter One of that code sets forth its statement of purpose as follows, "The purpose of this Code is to provide minimum standards to safeguard life or limb, health, property, and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location and maintenance of all buildings and structures within the city and certain equipment specifically regulated herein."

When governments establish codes to protect the public safety, certain problems such as cost and design flexibility are created.

The Problem of Cost

Public safety costs money. And there is more than one way to achieve the public safety objective of building codes. There are degrees of safety and variables in construction cost. The most expensive construction does not necessarily provide for the highest degree of public safety.

Design Flexibility

Since codes recognize that there is more than one way to design a safe building, there must be some freedom given to the architect to use a variety of building products or to design a building in varying configurations.

How do automatic sprinkler systems help solve some of these problems?

Let's take the problem of building costs first. Of all the items of cost measured by the U.S. Bureau of Labor Statistics, none has risen more rapidly than have construction costs.

Indeed the Federal Government – specifically the National Commission on Urban Problems, commonly known as the Douglas Commission, appointed by President Johnson–examined building codes under a federal microscope. They found a connection between the rising cost of construction and building codes.

How do automatic sprinkler systems help reduce building costs, under the provisions of building costs and how can some of the principles found in modern building codes be further implemented to help off-set the rising costs of construction?

Let's take a hypothetical example: A commercial building developer has decided to build a large shopping center. The shopping complex will be located outside of fire limits where parking space is available. Some of the stores he plans to build will be small, but other will be as large as 100,000 sq ft in area. All buildings will be one story in height.

The builder and his architect sit down together to decide how the building will be designed and built and to estimate the cost of construction. The architect suggests that a concrete and steel building be designed with 4 hr exterior bearing and non-bearing walls, 3 hr interior bearing walls, 3 hr protected structural frame, 2 hr floors, and a minimum of 1 hr rated interior permanent partitions. In a word, he was talking about a Type I building as defined in most modern building codes.

The selection of this type of construction would enable them to build to unlimited areas, a permission granted to no other type of construction. Heavy timber buildings, wood frame or unprotected steel buildings, could not be built to areas larger than a few thousand sq ft.

They priced out the job at $16/sq ft, including air conditioning but excluding an automatic sprinkler system, land costs and site work. The cost of it was too high.

They tried it another way. They decided to cost out the job by eliminating the 3 hr interior bearing walls, the 3 hr protection of structural frame members and then reducing all of the fire protection around permanent partitions, vertical openings, floors and roofs by 1 hr. In effect what they were designing was a bare steel building with brick exterior walls. This would be a Type III-N building under the Uniform Building Code – the code adopted in their locals.

The elimination of these fire protective reduced construction cost by $4/sq ft, or by $400,000 to cover the cost of the 100,000 sq ft mercantile they planned to build.

But one problem had not been solved. Despite the fact that the building was located outside of fire limits, with wide side yards on all four sides of the buildings, the building code would not permit any structure of this type to exceed 24,000 sq ft in area. And even if the code permitted its construction, who would insure its contents – or the building itself for that matter?

Looking to the *"Use and Occupancy"* chapter of the Code, they found that they could build this unprotected steel building *without any area limitation, if they installed an approved automatic sprinkler system throughout the building.*

Even after adding $.50 cents/sq ft for a sprinkler system, they found that they had a cost construction saving of $350,000 – a savings of about 23%.

This example really illustrates two principles found in most modern building codes: (1) automatic sprinklers can be used to reduce construction costs; and (2) automatic sprinklers can be used to augment the freedom of the architect to select different kinds of building materials and designs to protect the public safety.

Since we are talking about the principles of cost control in construction and design flexibility, let's take a look at some of these principles and see how they work and why they work.

Let's take a look at the thinking that lies beneath the permission granted by building codes to increase areas of buildings when sprinklers are installed (Fig. 1). This building could be the mercantile previously discussed.

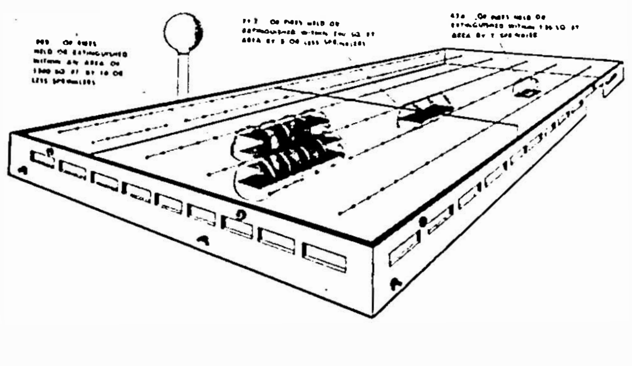

Fig. 1

The NFPA Sprinkler Performance Tables tell us that 43.6% of fires are held in check or extinguished by one sprinkler. Since ordinary hazard pipe schedules would protect about 130 sq ft of space, we can see that 43.6% of fires are held inside of an area of 130 sq ft. Three sprinklers within an area of 390 sq ft hold or extinguish 71.2% of fires; 89.9% of fires are held or extinguished within an area of 1300 sq ft by ten or less sprinklers.

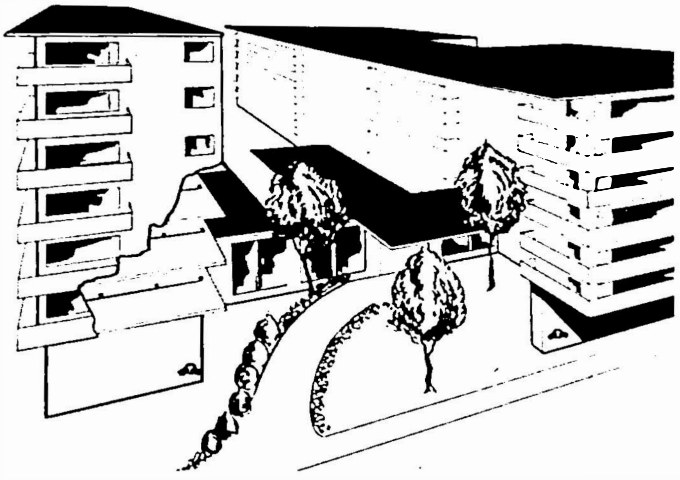

Fig. 2

Hence the basic reason for granting area increases in sprinklered buildings is because a small number of sprinklers keep fires within small areas by extinguishing them or controlling them in their incipient stages.

Fig. 2 shows a six story, Type V 1 hr (wood frame) apartment building. The building code where this building was erected, limits wood frame construction to three stories in height but permits an additional story if the building is sprinklered throughout. Since the building code only permits the addition of one story, or limits the height of a wood frame 1 hr protected building to four stories, why do we show this as a six story building? Because its our contention that if unlimited areas can be permitted, why not unlimited heights?

Obviously wood frame construction has certain structural limitations in terms of its load bearing capacity and from an engineering standpoint it would be unfeasible to build to more than six stories in height. Our purpose in showing you this building is to illustrate the principle, that in completely sprinklered buildings, the only limiting factor governing height increases should be structural engineering design, load and stress bearing factors, not fire protection.

Most building codes derive their exit requirements from NFPA Standard 101, "Safety to Life," which permits the distance between exits to be increased by 50% when sprinklers are installed. Fig. 3 shows a sprinklered school

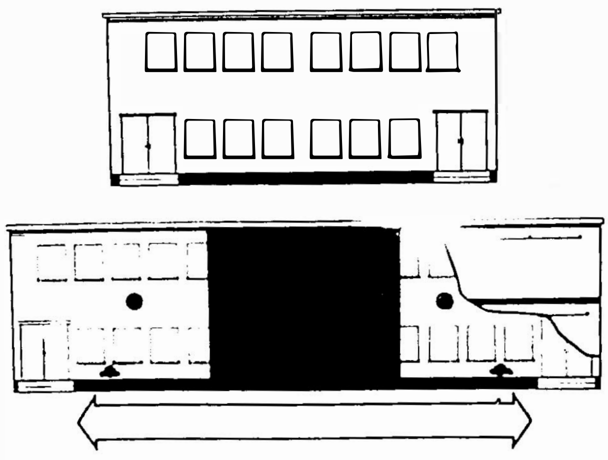

Fig. 3

(bottom) which is longer and has a greater distance between its exits than the unsprinklered school (top). The sprinklered school is allowed greater flexibility because the automatic sprinkleres extinguish the fire in its incipient stages making the building tenable from both the heat and smoke standpoint. This fact should give building occupants more time to evacuate; hence greater distance travel is permissible for sprinklered buildings.

This provision is found in all building codes that we know of. It has two effects from the standpoint of the architect, builder and owner: (1) It reduces construction costs by eliminating a stairway or by adding more useable floor space between exits. (2) It increases the architects design flexibility when he specifies automatic sprinkler systems.

Fig. 4 is a blank wall building. It has no windows on any side, is air conditioned and is provided with artificial light throughout. The only exits are on the main floor and the distance between exits is specified in the code.

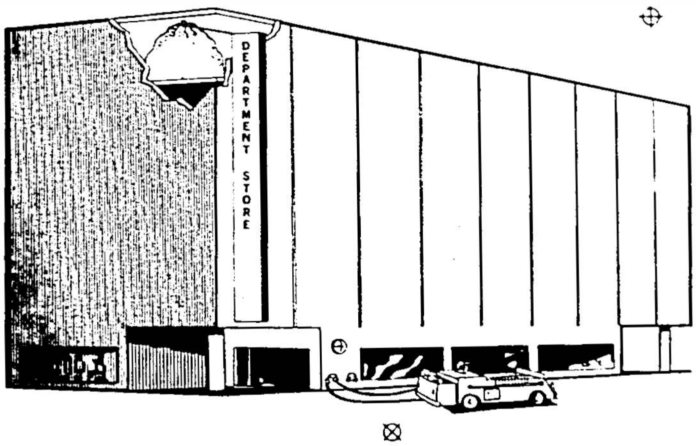

Fig. 4

This type of construction is becoming increasingly popular especially in mercantiles. Some cities have built experimental schools of this type of construction in areas having a high incidence of vandalism. Its considerably less expensive to build than windowed buildings. Temperatures within the building can be regulated more easily. But fire fighting is especially hazardous. There are problems with

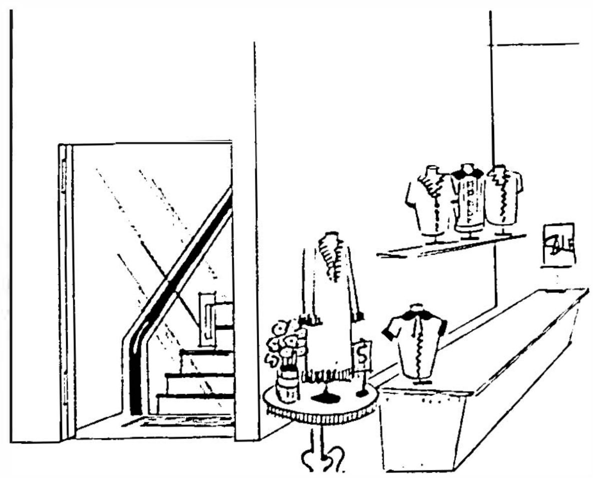

Fig. 5

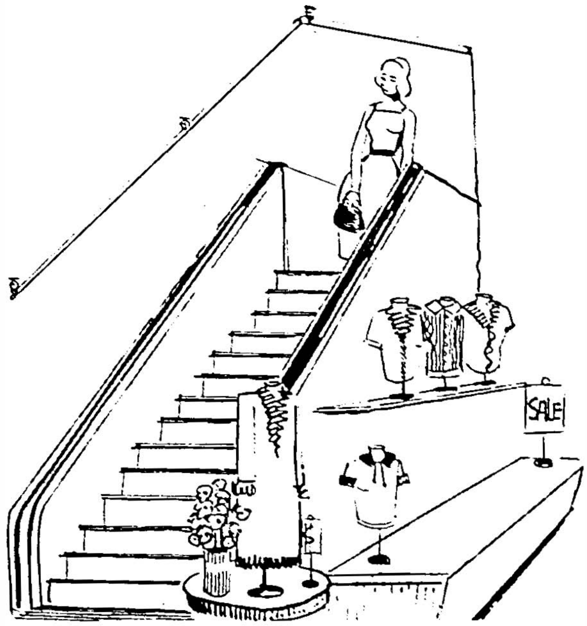

Fig. 6

venting such buildings. Most building codes require automatic sprinklers in these buildings. This building illustrates the fact that design flexibility is available to the architect and he is given the freedom to design such a building if he makes use of automatic sprinkler systems. Reduced construction cost is a by-product.

Fig. 5 shows an enclosed stairway in a mercantile. Some building codes permit the use of open stairways (Fig. 6) if buildings are sprinklered throughout, thereby allowing the architect greater design freedom.

Essentially escalators correspond to open stairways with regard to building codes. They normally do not constitute exits since they do not usually provide a means of egress

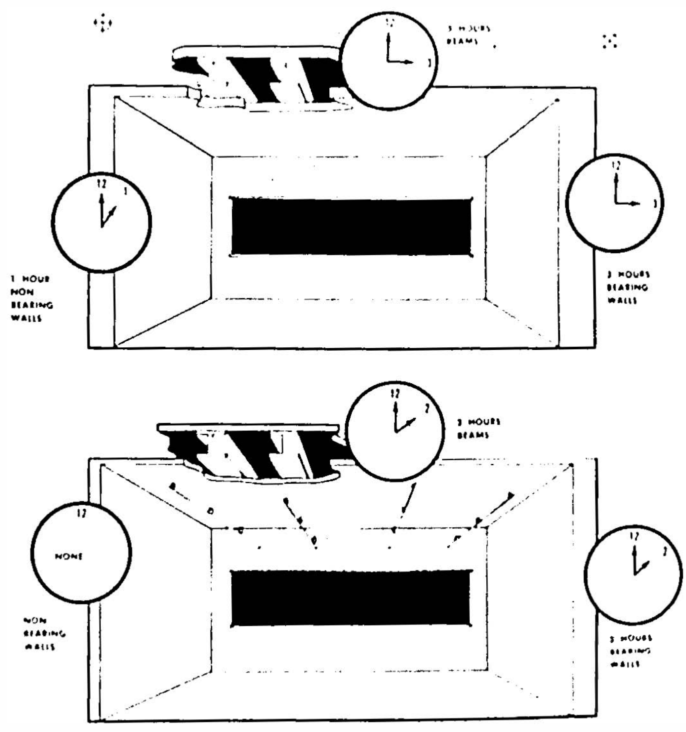

Fig. 7 and Fig. 8

to a public way outside of the building, although some building codes require the use of wired glass enclosures around escalators unless sprinklers are installed.

Figs. 7 and 8 indicate what happens to a building when an architect uses automatic sprinklers to move from a higher type to a lower type of construction. Notice that the fire protectives are reduced by one hour for bearing walls, ceilings and non-bearing walls. The result of this as we saw earlier, can bring about construction cost savings of 25% or more.

Fig. 9 is a high rise building. It resembles the Hartford Hospital where 10 patients died in a fire several years ago. Since that fire, there has been some agitation in the building code congresses to require automatic sprinklers in buildings over 80 ft in height, since most cities, especially smaller cities, do not have equipment capable of fire fighting or rescue at levels beyond 80 ft, since this is considered to be a maximum safe distance from which to perform rescues or to fight fires. Most fire department ladder equipment extend 85 ft vertically.

Automatic fire protection in high rise buildings will probably become mandatory over the next few years because a great number of these buildings are being built, especially in smaller cities. Rochester, Minn. was the first city in the U.S. to enact a mandatory requirement for sprinklers in high rise buildings. In New Haven, Conn., a 25 story office building is being sprinklered throughout. It is constructed of unprotected (bare) steel. To our knowledge, this building is unprecedented. Nevertheless, it is expected that this kind of building, sprinklered throughout, will become the prototype for high rise buildings in the future.

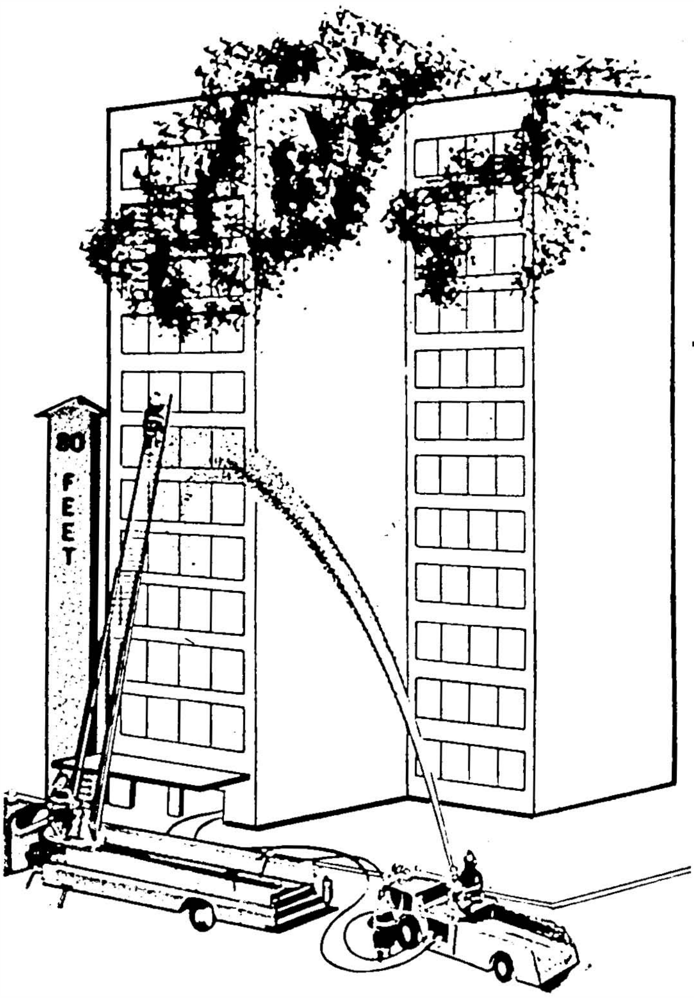

Fig. 9

CAN SPRINKLERS SYSTEMS SOLVE BUILDING CODE PROBLEMS?

We think you will all have to concede that the answer to that question is "yes." Because codes have recognized the value of automatic sprinkler systems, architects can design buildings with greater freedom than ever before. Construction costs are reduced and the public is given more safety from fire than any time in our history.

Enourmous advances have been made in building codes and especially in recent years. Code writers have exploited the advantages of automatic sprinklers to solve building code problems. But new problems are being created right now by some 21st century architect, engineer or designer who is thinking of some space age building that you and I have not yet conceived. And some how automatic sprinklers will play a part in the design of tomorrow's buildings.

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